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The Effect of Electronic Flight Bags in Flight Training on Preflight Skill Development and Aeronautical Decision Making

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This study was designed to evaluate the effects of utilizing Electronic Flight Bags (EFBs) in flight training with emphasis on preflight skill development and Aeronautical Decision Making. The study participants were student pilots or private pilots who used EFBs in flight training and had not logged more than 100 total flight hours. The study utilized a simulation of the preflight process of a Visual Flight Rules cross-country flight in which the participants answered questions related to the flight preparation. Fifty percent of the study's population completed this survey with the information provided through an EFB and the other 50% sample had to answer the questions without an EFB using traditional unabridged raw data. A comparative analysis of the data collected from both groups was performed. The largest degradation of performance was noted in Notices to Airmen (NOTAM) interpretation and the least degradation in performance was noted in weather-related decision-making.

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It is well known that most accidents in flight are initiated from a chain of events that originate from poor preflight preparation. Therefore, the Federal Aviation Administration (FAA) has placed considerable emphasis on the preflight portion of a flight. This is reflected in the pilot training curriculum and in Advisory Circular (AC) 60-22, which contains a detailed discussion on the "Poor Judgment Chain" (FAA, 1991). The introduction of Electronic Flight Bags (EFBs) has been readily accepted by pilots as a means to decrease workload and increase pilot efficiency.

Purpose

The purpose of this study was to investigate the impact of utilizing electronic flight bags in a flight training environment on preflight planning techniques, skill development, and Aeronautical Decision Making (ADM) of ab-initio pilots. Electronic Flight Bags are widely used by ab-initio pilots in the modern flight training environment. This study was initiated while considering the importance of meticulous preflight preparation and briefings for pilots and the impact EFBs have on modern ab-initio pilots. It is important to study the relationship between the usage of EFBs by ab-initio pilots, the impact of that usage on their preflight skill development, and their development of ADM skills. This study aims to address skill degradation in flight planning without the help of an EFB for pilots that started using EFBs very early in their flying career.

Research Questions

1. How has the introduction of EFBs in flight training curriculum impacted the knowledge of interpreting raw aviation data (such as Notices to Airmen, METARs, and Charts Supplements)?
2. Can ab-initio pilots display comparable levels of decision making when they do not possess an EFB to plan a flight and make decisions based on raw aviation products (unanalyzed and unprocessed data)?

Literature Review

The FAA issues guidelines for the use of EFBs to 14 CFR Part 91 operators in AC 91-78. This AC defines EFBs as an electronic display system intended for flight deck or cabin use. An EFB device can boost pilot performance by digitally displaying a variety of aviation data such as checklists, navigation charts, and the pilot's operating handbook (POH). EFBs even perform basic calculations in flight such as aircraft performance, load, and fuel calculations (FAA, 2007). Electronic Flight Bags are used in the flight training environment from a student pilot's first flight as well as by commercial airline pilots throughout their careers.

While the introduction of EFBs in flight training can be seen as a positive step to develop technologically-enabled and resourceful pilots, it is important to successfully carry out long-term risk analyses. Complacency and over-reliance have been rising issues with pilots using EFBs which give way to *automation dependency* that ultimately results in loss of *situation awareness* and *task saturation* when not using EFBs (Chandra, Yeh, Riley, & Mangold, 2003). Ab-initio pilots are also at risk of skill degradation due to excessive use of EFBs and not using raw products for decision making (Waldock, 2017). Skill degradation is the "loss or decay of trained or acquired skills (or knowledge) after periods of non-use" (Winfred, Bennett, Stanush, & McNelley, 1998, p. 58).

The FAA Human Factors Division studied the effects of EFBs on safety in flight in a 2014 report. This report included 276 voluntary safety reports from commercial operators in the United States. It was intended to study the impact of EFBs on flight safety, however, the report raised concerns including: lack of training or insufficient EFB training at air carriers, potential of distraction related to EFBs, storage of the EFB when not in use, and backup chart considerations (Chase & Hiltunen, 2014). Even though the safety reports were compiled from commercial airline operators, the implications also hold true for flight training.

The importance of such assessments stem from previous studies that studied the impact automation had on skill degradation and automation dependency. Winter et al. (2017) studied the performance of 29 pilots who held at least a private pilot certificate with an instrument rating. The study aimed to study pilot performance when using paper and electronic instrument approach charts. The performance of the pilots was significantly reduced when asked to complete tasks in instrument meteorological conditions without EFBs in a Flight Training Device (FTD) when compared to completed tasks with the help of EFBs. Not only did the researchers observe loss of control of the airplane when the pilots were not using an EFB, but also that pilots "felt the use of electronic charts reduced their workload as measured by the NASA Task Load Index (TLX)" (Winter et al., 2017, p.1).

Preflight Preparation

There has been a significant shift in the methodology used for preflight planning for flights. Significant technological advancements have changed the ways pilots can view meteorological data and other information pertinent to a flight. While technology changes, the elements of preflight preparation for a standard Visual Flight Rules (VFR) cross-country remain constant. Title 14 CFR 91.103 states that for "flights not in the vicinity of an airport, weather reports and forecasts, fuel requirements, alternatives available if the planned flight cannot be completed, and any known traffic delays of which the pilot in command has been advised by ATC" (FAA, 2018, p. 175). Furthermore, the pilot-in-command should be aware of all information relating to aircraft performance, airport elevation, runway slope, aircraft gross weight, wind, and temperature.

According to 14 CFR 91.103, sources that can be used for VFR flight information include: Sectional Charts, Chart Supplements, Notices to Airmen, the Airplane Flight Manual, and Weather Data for Aviation. Sectional Charts published by the Federal Aviation Administration are the main navigation reference tools used by pilots while flying under VFR. (FAA, 2018). Other than serving as a standard navigation tool for a standard VFR flight, the sectional aeronautical chart can provide wealth of information that a pilot can use such as information of radio aids for navigation, airports, controlled airspace, special use airspaces, obstructions, certain radio frequencies, runway lighting systems, special use airspaces, and other related data.

A Chart Supplement is published by the FAA and contains operational information for every civil use airport open to the public in the United States. This includes location, elevation, runway and lighting facilities, available services, availability of aeronautical advisory station frequency, types of fuel available, Flight Service Station (FSS) located on the airport, control tower and ground control frequencies, traffic information, remarks, and other pertinent information (FAA, 2016b, p. 6-17).

Notices to Airmen are a great tool for pilots to retrieve the latest information about an airport or any amendment to information published in the sectional aeronautical chart or the chart supplement. For a VFR flight, this information can be runway closures, change of taxiway signs, change in radio frequency, closure of airspace, and other details. The most updated NOTAMs can be retrieved online from the official Defense Internet NOTAMs Services website (PilotWeb), Flight Standards District Office, or a Flight Service Station.

An Airplane Flight Manual (AFM) is the document published and developed by the aircraft manufacturer. This document contains the information such on weight and balance, aircraft performance, take-off and landing data, and operating limitations. Title 14 CFR Part 91 requires pilots to comply with the operating limitations mentioned in the AFM.

Weather Data for aviation is managed and published by the National Weather Service (NWS), FAA, Department of Defense (DOD), and other agencies. Weather observations and forecasts can be found on the official website of the Aviation Weather Center (AWC) or can be obtained from a FSS briefing. The data published on the AWC website or FSS brief usually contains coded information or large scale charts.

Traditional sources for preflight planning data such as weather-related data are usually difficult to interpret and require significant experience to use, while testing a pilot's ADM skills to make safe and efficient decisions. The FAA (2009) explains this difficulty for general aviation pilots: "with many weather providers and weather products, it can be very difficult for pilots to screen out non-essential data, focus on key facts, and then correctly evaluate the risk resulting from a given set of circumstances" (FAA, 2009, p. 1). In terms of weather data, interpretation of data from raw sectional charts, NOTAMs, chart supplements, and raw weather data requires significant skills and knowledge of the codes and symbols. Also, estimating the actual implications of certain codes and symbols can be a challenging task. For example, in a standard weather observation such as a METAR or Terminal Area Forecast (TAF), the intensity of rain can be displayed as either –RA, RA, or +RA which symbolize *Light*, *Moderate*, or *Heavy* (FAA, 2016a).

Understanding aircraft performance and capabilities requires significant knowledge of the aircraft's systems and components. Airplane Flight Manuals are often bulky and contain large amounts of information pertinent to the aircraft model. Being well-aware of the aircraft's flight manual and knowing how to use the manual at different situations of planning also requires significant skill and experience. An electronic version of an AFM can be stored on an EFB making it easier for the pilot to find subject material and highlighted areas of importance.

Automation and EFBs in Flight Planning

The preflight planning for a typical VFR flight requires pilots refer to a wide variety of data sources and maintains knowledge and ADM skills to interpret raw data which is often coded. Electronic Flight Bags have made this process much easier for pilots. The introduction of EFBs have made it possible for all the data sources discussed in the previous section to be packed into a portable electronic device. Pilots no longer need to refer the chart supplements, raw weather data online, paper sectional charts, and physical AFM books to plan their flights. EFBs have the ability to superimpose information from various sources to deliver an enhanced preflight planning experience.

Pilots no longer need to be aware of METAR and TAF codes, formats of NOTAMs, and interpretation of performance charts in the AFMs. The EFBs can decode weather information into plain English, segregate NOTAM information according to the most significant notices for the date of the flight, present the information in easy-to-read language, and perform weight and balance or performance calculations for the pilots with the help of data input by the pilot just before a flight.

Rather than interpreting data from large scale charts such as Surface Analysis Charts, Weather Depiction Charts, or Radar Summary charts, pilots can now gain the same information by superimposing the data from the different weather charts and data sources onto the sectional charts and study the weather along the route flight. The capabilities offered by EFBs vary depending on the type of EFB used. Airline flight crews use more sophisticated and complex EFBs than typical pilots in a collegiate or flight training environment. Winter et al. (2017) argue that “EFBs increase safety because they provide more accurate information such as takeoff performance information using real-time data rather than data that has been rounded to the nearest 100 kgs [typical of paper charts because it is easier for humans to make these types of calculations]” (p. 2). The same can be applied to other factors of preflight planning such as weather data and airport data. Typically, pilots link the EFBs to the internet during preflight planning which allows the EFBs to update the data and ensure that the pilot does not operate the flight with any outdated or expired source of data.

Concerns

The primary concern this study aims to address is skill degradation in flight planning without the help of an EFB for pilots that have started using EFBs very early in their flying career. It is important that ab-initio pilots are well-versed to interpret and make safe decisions without the use of modern technology. That skill will likely be life-saving in a situation when an EFB fails or is not available. In the event of EFB failure, the pilots should be trained to be self-sufficient to make safe decisions.

Fundamental skill development is not only important for preflight planning, but also while flying the aircraft as well. Casner, Geven, Recker, & Schooler (2014) studied the impact of automation on manual hand flying skills by testing pilots who were currently flying in airplanes with significant automation "to fly with and without each automation system through three different phases of flight" (Casner et al., p. 3). Serious concerns were raised when pilots were tested on their "cognitive skills that accompany manual flight" (p. 9) Pilots struggled to maintain situational awareness along different intervals of the flight and struggled to deal with emergencies while manually flying the airplane.

Research by Milner et al. (2017) studied the impact of EFBs on the response time of pilots to questions on given instrument approach plates. The study utilized a survey of 30 questions that consisted of inquiries related to different elements of approach plates presented by the investigators. The participant could use an EFB to answer the first 15 questions but had to rely on paper copies for the last 15 questions. The authors observed that response time was much quicker when the participants used EFBs rather than paper charts.

Methodology

This study was an applied research study with a mixed factorial design with within-subjects survey and between-subjects experimental components. This study was conducted at Embry-Riddle Aeronautical University, Daytona Beach, Florida. The participants were required to be either student pilots or private pilots and must not have logged more than 100 flight hours at the time of participation. The study focuses on this population because the population is inexperienced and in the process of skill development to be proficient pilots.

The sample size for this study was 40 participants. To achieve optimum results, a two-fold survey was designed. The study composed of a general opinion survey and a scenario-based simulation survey.

Sample Selection

The participants of this study were randomly chosen student pilots or private pilots who used EFBs in their flight training and had not logged more than 100 total flight hours. The study was advertised in the premises of the College of Aviation building of Embry-Riddle Aeronautical University, Daytona Beach through printed flyers. Any participant that wished to participate was able to contact the researcher through email. Participation in this study was voluntary and the participants were not compensated for their participation. The participants were students of Embry-Riddle Aeronautical University, Daytona Beach. Sixty percent of the participants were student pilots and the remaining 40% were private pilots. The average flight experience of all 40 participants was 58.1 total flight hours.

This study focused on pilots in the flight training environment and the participants were student pilots or private pilots with less than 100 flight hours. The study focuses on this population because the population is inexperienced and in the process of skill development to be proficient pilots.

More experienced pilots with more flight hours are less likely to have started their flight training with EFBs and their experience in different flight conditions would have an influence on their skill development, too. For this reason, testing inexperienced pilots with either a student or a private pilot certificate with less than 100 flight hours was decided to be the most appropriate population to study skill development in a flight training environment.

General Opinion Survey

Purpose. The purpose of the general opinion survey was to derive qualitative data from the participants on their dependency on EFBs, their decision-making process with and without EFBs, and their preparation methods for flights. All 40 participants taking part in this study took this survey. The survey derived responses from the participants to 10 statements relating to preflight planning methods and their dependency on EFBs. The list of questions is provided in Appendix A. The data was analyzed to identify trends and behavioral characteristics of EFB users on various cases presented through the survey questions.

Procedure. The survey was administered via Google Forms and data was gathered from March 2018 to April 2018. Participation was voluntary and the participants were not paid for their participation. The Embry-Riddle Aeronautical University Institutional Review Board authorized the study under protocol number 18-127. The survey was conducted in a tutoring lab in the College of Aviation of the University where the students were provided a computer to answer the questions. The participants were allowed to either use the EFB provided by the researcher or use their own EFB for the study. The EFB used for this study was Foreflight on an Apple iPad, as it was the only mandated EFB in the university's flight program (Embry-Riddle Flight Department, 2018). The questions in the general opinion survey were aimed at obtaining insights into operating practices of the participants and the influence EFBs had on those practices. All but two questions required participants to respond through Likert scales.

Scenario

Purpose. The purpose of the scenario survey was to derive quantitative data to measure the performance of the participants in the preflight scenario simulation. All 40 participants responded to this survey, but 20 participants used an EFB to answer the questions and the other 20 did not use an EFB to answer the questions. Participants were assigned to each group on an alternating basis. The first participant of the survey was assigned to the group that could use an EFB and the second participant was assigned to the group that could not use an EFB. This pattern of alternating the groups was followed for the 40 participants.

Scenario description & procedure. The scenario for this simulation was a Visual Flight Rules (VFR) Cross-Country from McGhee Tyson Airport (KTYS) in Knoxville, Tennessee to Dover Air Force Base (KDOV) in Delaware on March 18, 2018, at 0100Z. The researcher had selected this route on March 18, 2018, as it presented a challenging route in terms of weather and other factors such as the Washington Special Flight Rules Area present along the route of flight. The route had patches of Instrument Metrological Conditions and areas of thunderstorms during the time of the flight. The route of flight presented an opportunity for pilots to advertently enter IMC and the Special Flight Rules Area without adequate planning. At 0100Z, the researcher collected all the pertinent weather data through ForeFlight, Aviation Weather Center, and DUATs to create the weather packet that was provided to the participants for the study. The researcher also used PilotWeb and ForeFlight to retrieve all the NOTAMs published for that time to include in the packet.

The participants that were not allowed to use an EFB were provided with a printed weather briefing from DUATs and weather charts such as the Surface Analysis Chart, Weather Depiction Chart, and Radar Summary Chart from AWC. They were also provided with printed NOTAMs from PilotWeb and Chart Supplements for the airports required in the scenario, and the sectional chart.

The participants that could use an EFB were provided the screenshots of the weather briefing from Foreflight and the screenshots of the NOTAMs from ForeFlight for the time of the flight. All the other data needed for the study could be retrieved from ForeFlight while completing the study.

Time critical information like weather data and NOTAMs was provided to the participants allowed to use an EFB through printed screenshots derived from Foreflight during the time of the simulated flight. All other data needed to answer the questions could be derived from the EFB used by the participants at the time they took the survey.

The group that was not allowed to use an EFB was provided with NOTAMs, chart supplements, a VFR Sectional Chart, and a printed weather briefing from Flight Service Station (DUATS) and ADDS Aviation Weather Center.

Data analysis. The scenario survey was analyzed under four categories: NOTAMs, Charts Interpretation, Weather Products, and Flight Information/Awareness. Participants had to answer 15 questions on the basis of a provided flight scenario from McGhee Tyson Airport (KTYS) in Knoxville, Tennessee to Dover Air Force Base (KDOV) in Delaware on March 18, 2018, at 0100Z. The four categories are critical components of planning any VFR Cross Country flight and were coherent to the information a pilot is required to obtain before a flight as per 14 CFR 91.103.

NOTAMs interpretation was tested from three separate incidents where the participant pilots needed to verify the runway status at KTYS, change in radio frequencies at KDOV, and detect a Temporary Flight Restriction along the route of flight. For this information, the participants could have referred to the list of NOTAMs for both the airports and all the airspaces for the entire route. A challenging aspect of not using an EFB for NOTAMs in the scenario was the sheer volume of NOTAMs and the varying subjects the NOTAMs addressed which made it difficult to segregate information, especially for ab-initio pilots. The pilot who could use an EFB (G2) were handed out briefs from Foreflight which categorized NOTAMs *Navigation*, *Communication*, *Service*, and *Obstructions within 10NM*. The illustration and segregation of complex data by the EFB is expected to play a major role in aiding participants in detecting relevant NOTAMs implementing them in their flight plans.

The participants who were not allowed to use an EFB (G1) were provided with a printed Flight Service Station (DUATS) brief for the flight and were provided with all the latest weather charts such as the radar summary charts, surface analysis charts, and weather depiction charts. Interpreting the weather data for this flight was a challenge as the weather did considerably change along the route of flight. G1 participants had to rely on data such as METARs and TAFs of the airports en-route, AIRMETs/SIGMETs/Convective SIGMETs, and weather charts. G2 participants were provided with the briefing available on the Foreflight application that was used for this study. The briefing utilized extremely illustrative methods to display the weather data. Airports along the route that did experience Instrument Flight Rules (IFR) weather were labelled red and those that experienced VFR weather were labelled green. Radar data can be superimposed on the exact route of flight with an illustration of the exact rate and direction of the thunderstorm cells. The areas for which AIRMETs, SIGMETs, and Convective SIGMETs have been issued can be shaded on the sectional chart with the advisory superimposed on the digital sectional chart. Information that is usually retrieved from different areas can now be consolidated and superimposed on each other to aid the pilots.

For the purpose of the analysis, all questions were categorized based on the proficiency they tested. The questions of the survey were analyzed under *NOTAMs*, *Charts Interpretation*, *Weather Products*, or *Flight Information/Awareness*. There were multiple questions that tested a single proficiency area; hence, the figures presented in the results represent the average scores of the participants of the two groups in each proficiency area. The NOTAMs category had four questions, Charts Interpretation had two questions, Weather Products had three questions, and Flight Information/Awareness had seven questions.

Appendix A lists all the questions that were included in the scenario survey of the study. The questions were categorized under NOTAMs, Charts Interpretation, Weather Products, or Flight Information/Awareness as the following:

- NOTAMS
  - You take-off and need to return back immediately. You can only land back on Runway 5. Can you land on Runway 5?
  - What is the current ATIS frequency at KDOV?
  - I do not need to worry about any TFRs on my route.

- Charts Interpretation
  - How do you plan to open your flight plan after taking off at KTYS?
  - Before you reach KDOV, you decide to divert to KAPG. Can you fly through R4001-A to reach KAPG. The time is 1:10AM Local on 18th March 2018. What is the status of the airspace? How do you verify it?

- Weather Products
  - There is considerable risk of me encountering IFR weather on the way
  - Refer to the radar imagery presented to you. There is considerable risk for me to cancel the flight or divert to different airport.
  - Examine the weather of PAVA airport. It is safe for me to land at the airport with a plane not equipped with anti-ice systems.

- Flight Information/Awareness
    - What fuel services would you be able to get in KTYS?
    - KTYS is an airport designated as an "Airport of Entry".
    - What are the noise abatement procedures at KTYS?
    - How do you plan to open your flight plan after taking off at KTYS?
    - On the way back to KTYS from KDOV I notice that that I am low on fuel. I land at KMKJ to take a break at 0730 Local time on 18th March. I expect the airport to be attended.
    - What is the Traffic Pattern Altitude at KDOV?
    - While en-route, you take a break at Lake Anna (7W4) Airport. What fuel services do you expect at that airport?

The average percentage scores of participants in each category have been scaled to a score of 20. The calculation of the score can be understood below:

Total questions in category: Q
Average score of G1/G2 participants in Category: X
Average Percentage: (X/Q) multiplied by 100=Y
Y scaled to a score of 20: (Y/100) multiplied by 20

A scale of 20 was chosen because the scale allowed the performance scores of G1 and G2 in each category to be distinguished easily on a graph. The scale of 20 was deemed appropriate for this analysis. The average percentage in each category can be scaled to any score for analysis and graphical display.

Results

The question addressed in Figure 1 serves as a self-evaluation for the participants for their self-confidence to read and interpret raw weather data. The number of people who do not feel confident of reading raw weather products outnumber the number of people who feel confident reading and interpreting raw weather data.

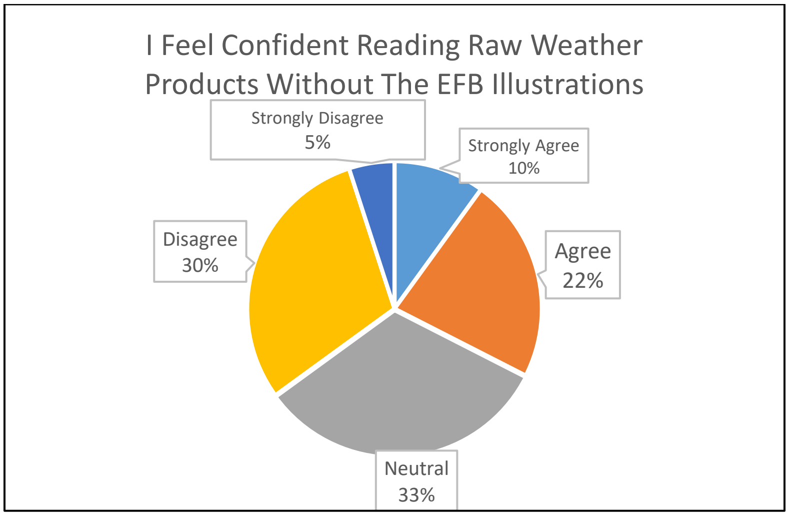

Figure 1. Interpreting raw weather products without EFB illustration.

The question addressed in Figure 2 is intended to get an insight into the operating practices of the participants. The majority of the participants do not carry printed NOTAMs and weather briefings to the flight when they do not use an EFB.

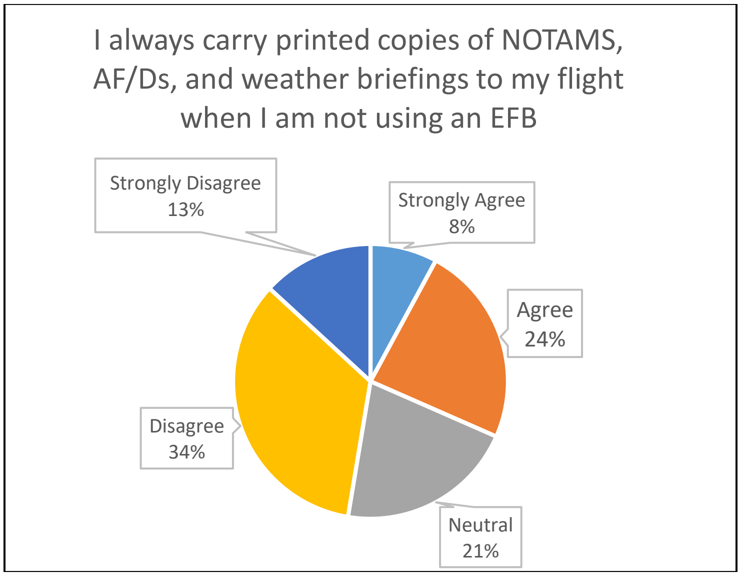

Figure 2. Printed products carried by pilots in flight.

The question addressed in Figure 3 is intended to get an insight into the planning methodology of the pilots when they do not use an EFB for preflight planning. A majority of pilots approximate headings, ground speeds, and timings when they do not use an EFB.

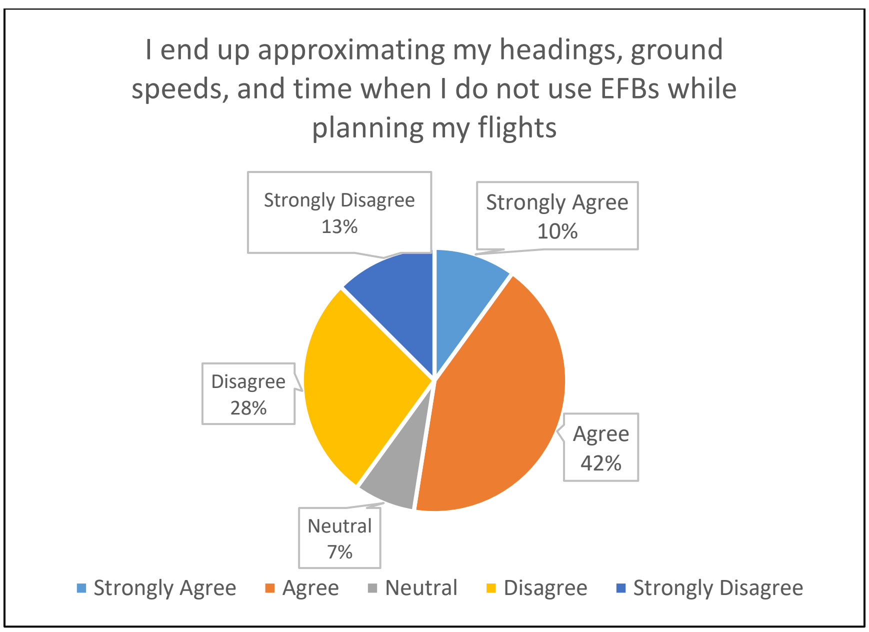

Figure 3. Approximation of navigation information when not using an EFB.

The question addressed in Figure 4 is intended to get an insight into the operating practices of the participants. The majority of the participants do carry back-up paper copies of charts and checklists and a manual plotter for their flight.

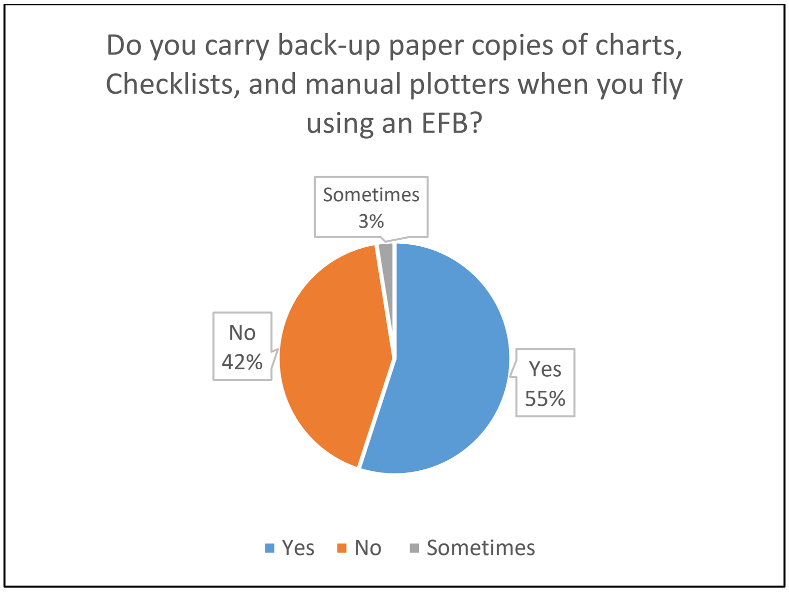

Figure 4. Backup products carried by pilots.

The question addressed in Figure 5 serves as a self-evaluation for the participants to evaluate whether they feel more proactive when using an EFB for preflight planning. A large majority of the participants do feel more proactive when planning a flight with an EFB.

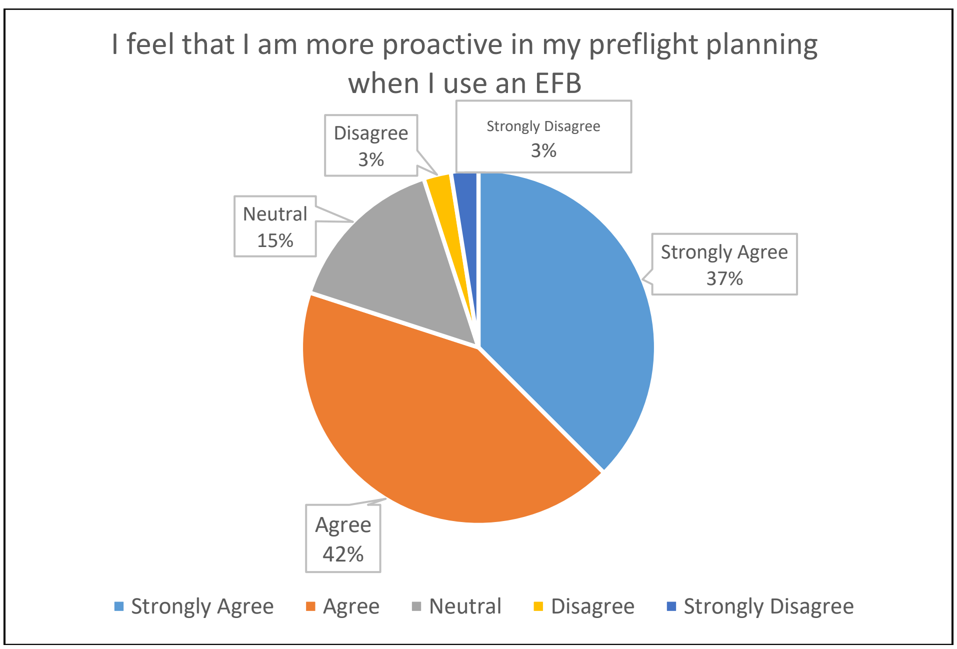

Figure 5. Participants feeling more proactive while planning with EFBs.

The question addressed in Figure 6 serves as a self-evaluation for the participants to assess their self-confidence to use a manual navigation plotter in flight. The majority of the study population does feel confident when using a manual navigation plotter in flight if the EFB fails.

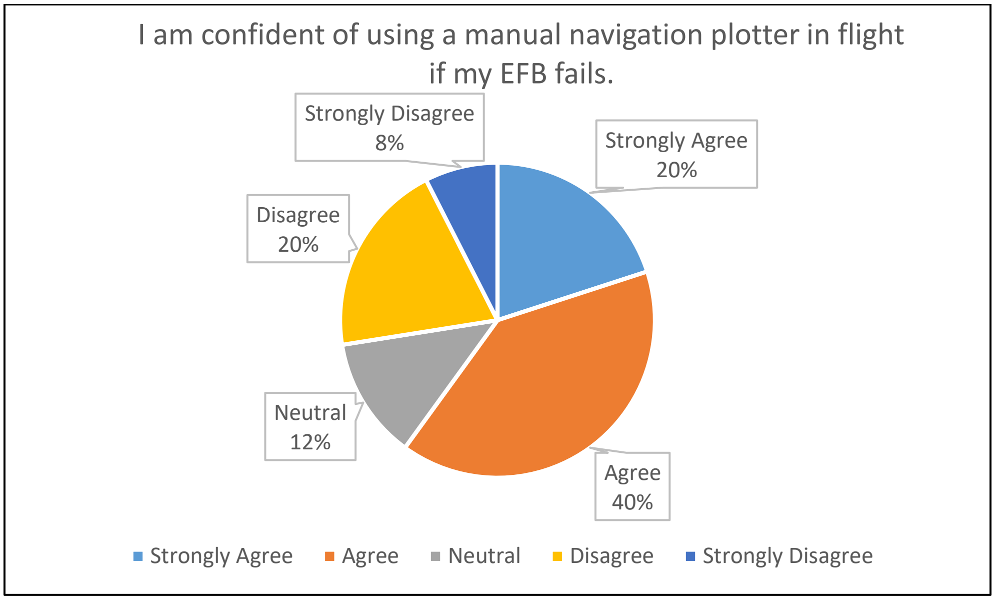

Figure 6. Using Manual Navigation Plotter in Flight.

The question addressed in Figure 7 serves as a self-evaluation for the participants to assess the impact of using EFBs on their fundamental skill development and data interpretation. A slight majority of participants feel that using EFBs in their flight training has a negative impact on their skill development and data interpretation skills.

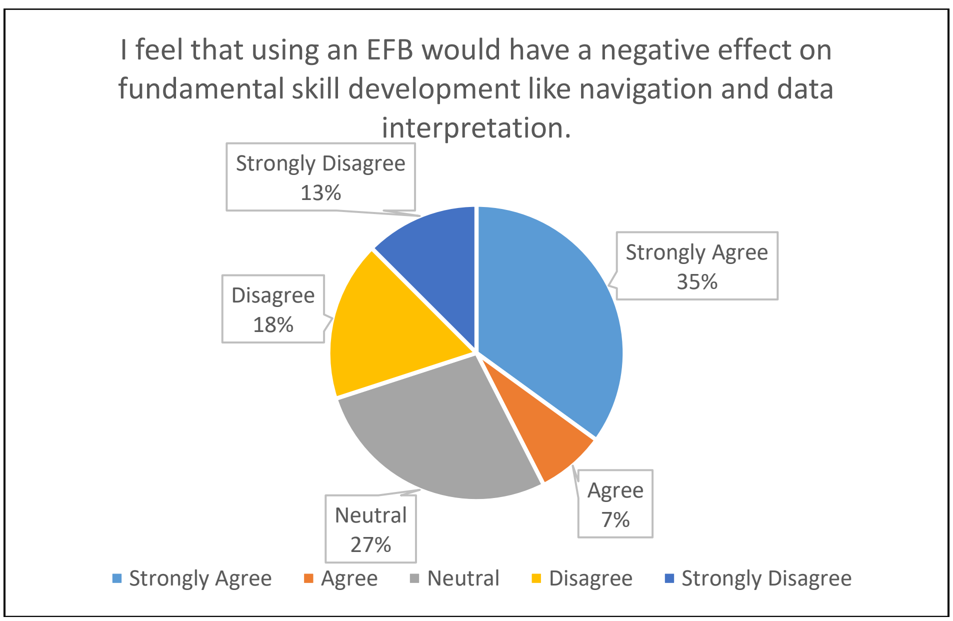

Figure 7. Effect of EFBs on skill development and data interpretation.

The question addressed in Figure 8 is intended to get an insight into the flight planning procedures of participants. The majority of participants are aware of the alternate airports they can land, but do not read the NOTAMs, chart supplements, and weather briefings for those airports.

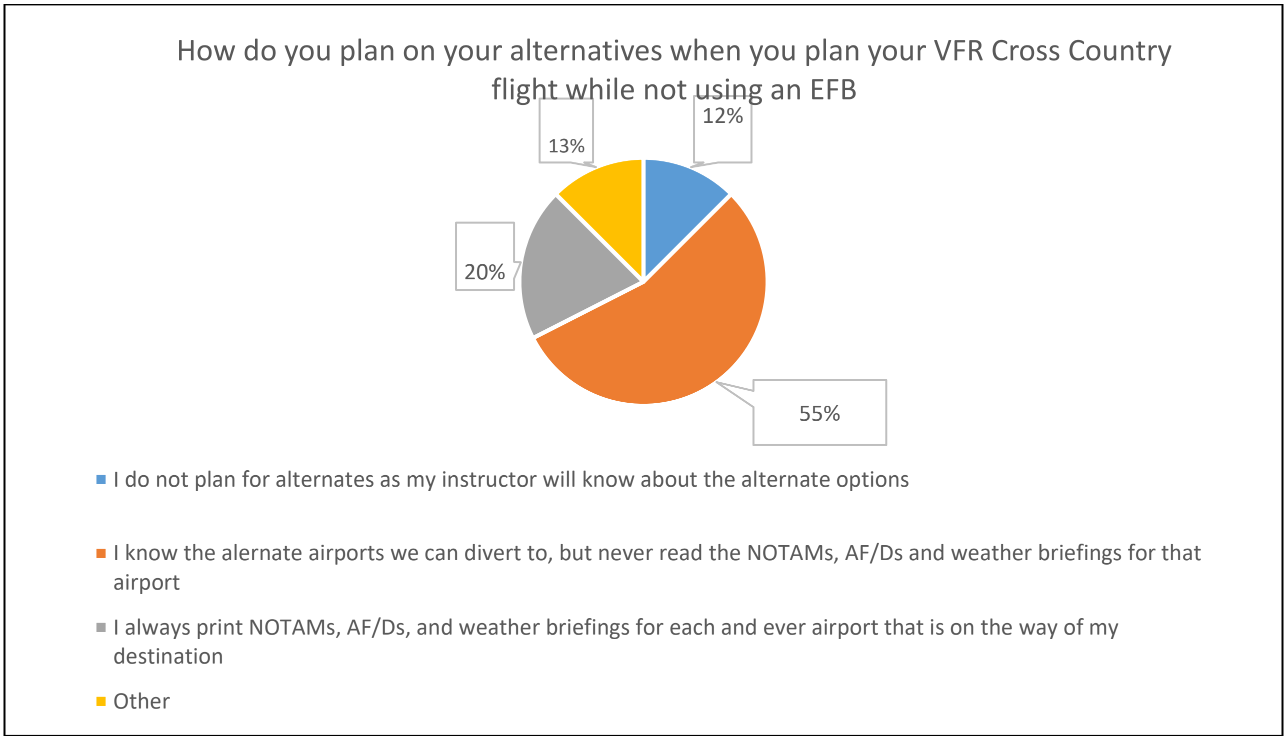

Figure 8. Planning of VFR cross-country alternates.

Scenario Survey Results

The scenario simulation required the participants to plan a VFR cross country flight from KTYS to KDOV on March 18 at 0100Z. The participants were questioned on multiple aspects of their flight planning such as alternate options, their decisions in response to weather reports in flight, the status of airspaces, and the information about the airports they intended to land or take-off.

For the purpose of non-wordiness, the groups will be referred to as the following:

- G1: Participants that did not use an EFB for the scenario
- G2: Participants that used an EFB for the scenario

Some of the outstanding observations from this study include:

- 85% of G2 were able to detect the Washington Terminal Flight Restriction (TFR) in comparison to 65% of G1
- 75% of G2 were able to determine a runway closure at the destination airport in comparison to 55% of G1
- 70% of G2 were able to determine the status of a restricted airspace in comparison to 60% of G1
- 65% of G2 were able to detect the change in radio frequencies at the destination airport in comparison to 35% of G1

For the purpose of the analysis, all questions were categorized on the basis of the proficiency they tested. The questions of the survey were analyzed under *NOTAMs*, *Charts Interpretation*, *Weather Products*, or *Flight Information/Awareness* (see Figure 9). There were multiple questions that tested a single proficiency area; hence, the figures presented in this section represent the average scores of the participants of the two groups in each proficiency area.

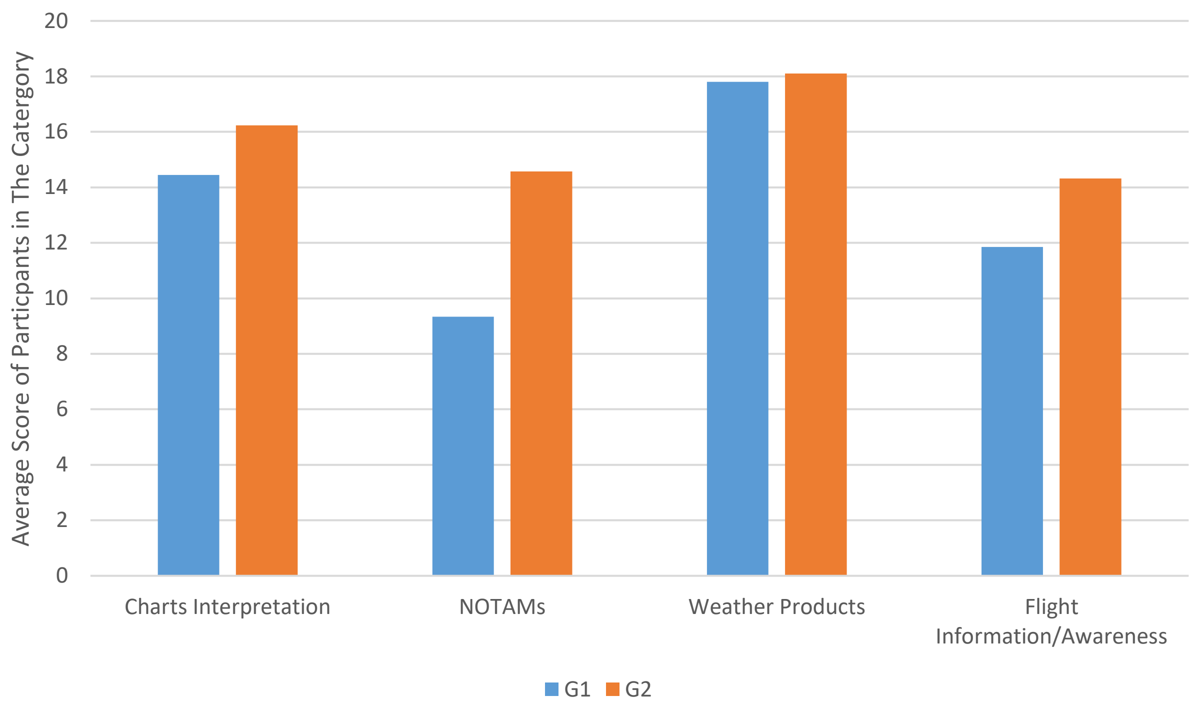

Figure 9. Performance analysis of participants in scenario survey.

Discussion

The purpose of the study was to evaluate the effects of utilizing Electronic Flight Bags in flight training with emphasis on preflight skill development and Aeronautical Decision Making. While the general survey served as a self-evaluation tool for the participants to provide data about their operating and flight planning practices, the scenario survey served as a tool to evaluate the differences in performance when participants accustomed to using EFBs regularly are required to plan the same flight with and without an EFB. The results of this study are relevant to current flight instructors, flight training administrators, and members of the collegiate aviation community to ensure that student pilots of today are self-reliant and safe professional pilots in the future.

While 79% of the participants felt more *proactive* while planning their flights with EFBs, there was a large degradation in preflight performance of the G1 participants that were not allowed to use an EFB for the scenario survey. The least degradation was observed when participants were asked to make decisions based on weather scenarios. The largest degradation was noted in NOTAMs interpretation.

It was noted that considerably fewer G1 participants were able to detect the Washington Special Flight Rules Area (SFRA). The added illustration of a red shaded circle superimposed on the sectional chart in the EFB aided the pilots using the EFBs to detect the Washington SFRA. The G1 participants only had a lengthy DUATs briefing and a navigation chart to help them identify the Washington SFRA. Pilots using EFBs were also able to perform slightly better than the G1 participants in questions related to weather data interpretation and decision-making along the route. The EFB was able to accurately depict the exact position and movement of thunderstorm cells, areas of Instrument Meteorological Conditions, and icing conditions by superimposing radar imagery and graphical illustrations on the sectional chart. Similarly, G2 participants were able to detect relevant NOTAMs more easily than G1 participants because the EFB segregates NOTAMs according to the time, duration, and status of the NOTAM. G2 participants were able to perform better on questions related to airport closures, fuel availability, frequencies, and traffic pattern altitudes because of the convenient segregation and presentation of data for each airport by the EFB. The G1 participants only had the chart supplements for the airports to answer the questions.

It is relevant to note that the largest degradation in performance of G1 participants in comparison to G2 participants was seen in this category. It is vital for ab-initio pilots using EFBs for their flight planning to develop the skills of detecting relevant information from airport and airspace NOTAMs without the use of EFBs as ignoring NOTAMs can not only hamper the safety of flight, but also place the pilots in risk of regulatory violation

Charts Interpretation was tested at two separate incidents in the scenario. A major area that was tested under Charts Interpretation was detecting the airspace status of the Restricted Area R 4001-A near Phillips Army Field (KAPG) in Maryland. As explained in the Aeronautical Information Manual under Section 4. 3-4-3, restricted airspaces are critical because "penetration of restricted areas without authorization from the using or controlling agency may be extremely hazardous to the aircraft and its occupants" (FAA, 2018, p. 659). To ensure safety of the flight, it is critical that pilots are well-aware of the status of airspaces that they plan to fly though. This skill extends beyond detecting restricted airspaces and is applicable to detecting any sort of airspace pilots might be flying through such as Military Operations Area, and Prohibited Areas For the participants that could not use an EFB (G1), there were multiple methods to obtain information regarding the status of the R 4001-A restricted area, one of which was referring to the keynotes in the sectional chart that was provided to them. Another method that pilots can use to detect the status of airspaces without a sectional is contacting an appropriate Flight Service Station of Air Traffic Controlling Agency. The keynotes section is the only method to obtain information regarding the restricted areas from the sectional charts. For the participants that were using an EFB for this survey (G2), the status of airspace was superimposed on the digital sectional chart on the Foreflight application. If the restricted airspace is shaded red, it implies that the restricted airspace is active and if the airspace is shaded orange/tangerine, it implies that the airspace is inactive. The possibility to consolidate information makes is easier for pilots to interpret navigation charts as a lot of information that is not available in normal physical copies of the sectional charts is superimposed on the digital sectional charts used on EFB software and applications. Pilots used to utilizing such digitalized versions of navigation charts might find it difficult to navigate and search for information when they are disabled of such application.

Weather interpretation is a key skill that needs to be inculcated in all pilots and developing that skill from the ab-initio level is extremely important. Weather data is disseminated to pilots from a variety of sources. It is important for pilots to not only interpret and make safe aeronautical decisions from the limited data they have, but also make sure that the data they are using to base their decisions are credible. Pilots often have to work with very little data to make safe decisions. Interpreting products such as radar summary charts, prognostic charts, surface analysis charts, and weather depiction charts which deliver weather data on a very large scale can be challenging for ab-initio pilots and make it difficult to interpret data for a particular route of flight within the country. This is fine when ADM skills come in play and the skill of interpreting the limited data to make decisions is critical.

Ab-initio pilots who have been trained early in their flight training with such illustrated and abridged data from EFBs might find it difficult to use raw data in a situation using an EFB is not possible.

Flight Information and Awareness is critical for the safe operation of any flight. This includes pilots ensuring planned airports for take-off, landing, refueling, alternates are attended to avail services, planning appropriate en-route and destination alternates to ensure that the appropriate services are available, and ensuring that all listed precautions and procedures listed for the airspaces and airports such as noise abatement procedures are adhered to. It is vital for pilots to attain the skills and knowledge to retrieve data from different sources to not only make the safest decisions, but also comply with regulatory and other advisory procedures. Ab-initio pilots that initiate their flight training with EFBs do possess a lot of information at their fingertips as modern EFBs de-clutter all important data about airports from sectional charts and Chart Supplements and present them in formats that are much more user-friendly. In situations when these pilots do not have the EFBs to retrieve this information, it is vital that such ab-initio pilots are trained to maintain the same level of proficiency in flight planning and being resourceful to retrieve data from different sources.

Limitations

The population of this survey was limited in its scope and sampling precludes generalization of findings. All the participants of the study were pursuing their flight training at the same flight training department of the university. Certain trends and results which were noticed might not be true for the general population but might only be true for the localized population from the university that is undergoing the same structure of training. A similar study with more participants and multiple institutions and geographical areas is recommended for further studies.

Conclusion

It can be concluded that while the introduction of EFBs is a welcome addition to flight training, considerable emphasis needs to be placed by flight training administrators to ensure that students are well-trained to sustain fine ADM and data interpretation without EFBs as well. Ab-initio pilots are very vulnerable to developing hazardous attitudes and unsafe flight planning techniques due to inexperience and retain those techniques further on into their careers due to the principle of primacy.

Through this study, we observed that the introduction of EFBs in flight training can have an impact in terms of fundamental skill development for preflight planning as participants that did not have an EFB for the study performed worse on the scenario simulation than the participants who were able to use the EFB. Participants who were not allowed to use an EFB performed worse in interpreting NOTAMs, sectional charts, Chart Supplements, and weather data. Decision making was evaluated in the scenario survey mainly through weather products. The route of flight did contain Instrument Metrological Conditions and the radar images did predict thunderstorms in the vicinity of the route planned for the flight. The results of the scenario survey showed that participants who did not use an EFB for the survey were less likely to detect weather-related hazards. Even in terms of airspace closures and regulations, participants that were not allowed to use the EFB performed worse when required to detect the Washington SFRA and Restricted Area R4001-A.

Ab-initio pilots are not exposed to decision making while utilizing raw data in the modern training environment where pilots use advanced EFBs in the early stages of their flight training. The ease of preflight planning with EFBs can have a negative impact on the ability of ab-initio pilots to interpret, analyze, and make decisions when not using an EFB. Pilots can either become complacent while referring to briefs and miss out on important information such as SFRAs, airport restrictions, or airspace closures or pilots can also be overwhelmed with the amount of data that is normally presented in an FSS briefing which can span several pages when printed. Interpreting and analyzing large amounts of data to make decisions is an important process that every pilot needs to be proficient in and the usage of EFBs in the early stages of flight training can hamper the development of this skill. It is important for flight instructors to ensure that while students who use EFBs are well-equipped with the latest technology to better prepare them for the future, students should also be well-trained to deal with EFB and other automation failures and be proficient in using other resources.

This study analyzed the impact of the introduction of EFBs in flight training curriculum on the knowledge of interpreting raw aviation data (such as Notices to Airmen, METARs, and Charts Supplements). The results of this study indicate that when ab-initio pilots use EFBs during the initial stages of their flight training, there may be a negative impact on their knowledge of interpreting raw aviation data. Participants who were not allowed to use an EFB in the study scored lower on the scenario-survey than the participants that could use an EFB. This was evident in all four categories (NOTAMs, Weather Products, Flight Information/Awareness, Charts Interpretation) that the questions were categorized into. The largest degradation in performance was noted in NOTAMs interpretation.

This study also analyzed whether ab-initio pilots display comparable levels of decision making when they do not possess an EFB to plan a flight and make decisions based on raw aviation products (unanalyzed and unprocessed data). The results of this study indicate that when ab-initio pilots use EFBs during the initial stages of their flight training, there may be a negative impact on their decision-making skills during flight planning when not using an EFB. This was evident in the scenario survey when participants who did not use an EFB were less likely to detect IFR conditions, thunderstorms, closed runways in airports, and restricted airspaces in their route of flight while planning their flight. Because this study used a relatively small sample size and was localized to one university's flight training department, the researchers recommend further research in the area of EFBs and flight training.

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Appendix A

Survey Questions

General Survey

- I Feel Confident Reading Raw Weather Products Without The EFB Illustrations
- I always carry printed copies of NOTAMS, AF/Ds, and weather briefings to my flight when I am not using an EFB
- I end up approximating my headings, ground speeds, and time when I do not use EFBs while planning my flights
- Do you carry back-up paper copies of charts, Checklists, and manual plotters when you fly using an EFB?
- I feel that I am more proactive in my preflight planning when I use an EFB
- I am confident of using a manual navigation plotter in flight if my EFB fails.
- I feel that using an EFB would have a negative effect on fundamental skill development like navigation and data interpretation.
- How do you plan on your alternatives when you plan your VFR Cross Country flight while not using an EFB

Scenario Survey

Flight Details

You are flying from KTYS to KDOV on 18th March 2018. Your take off time is 0100Z. All weather data and NOTAMs provided are current as of 0100Z on 18th March 2018. If any questions requires data interpretation or decision making at a time other than 0100Z, the particular question will state the time and corresponding data will be provided to you. For participants using EFBs, you have been provided with only the weather data and NOTAMs as of 0100Z March 2018. You should use the EFB for all the other data required in this survey. For participants not using an EFB, you are provided with the route on a sectional chart(Not to scale) and the AF/Ds as well on top of the weather and NOTAMs.

- What fuel services would you be able to get in KTYS?
- KTYS is an airport designated as an "Airport of Entry". True or False?
- What are the noise abatement procedures at KTYS?
- How do you plan to open your flight plan after taking off at KTYS?
- You take-off and need to return back immediately. You can only land back on Runway 5. Can you land on Runway 5?
- I do not need to worry about any SFRAs on my route.
- There is considerable risk of me encountering IFR weather on the way
- Refer to the radar imagery presented to you. There is considerable risk for me to cancel the flight or divert to different airport.
- Before you reach KDOV, you decide to divert to KAPG. Can you fly through R4001-A to reach KAPG. The time is 1:10AM Local on 18th March 2018. What is the status of the airspace? How do you verify it?
- On the way back to KTYS from KDOV I notice that that I am low on fuel. I land at KMKJ to take a break at 0730 Local time on 18th March. I expect the airport to be attended.
- What is the ATIS frequency at KDOV?
- What is the Traffic Pattern Altitude at KDOV?
- Examine the weather of PAVA airport. It is safe for me to land at the airport with a plane not equipped with anti-ice systems.
- While en-route, you take a break at Lake Anna(7W4) Airport. What fuel services do you expect at that airport?