EVALUATING THE EFFECTIVENESS OF FITS TRAINING

This study evaluates FAA/Industry Training Standards (FITS) training in (a) improving judgment and decision making skills, (b) improving automation management skills, and (c) improving situational awareness. It also determines the difference between FITS, non-FITS, and no training students upon the completion of a transition training course, and the specific strengths and weaknesses of FITS training.

by

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Executive Summary

The aviation community recognizes a need for at least one order of magnitude improvement in general aviation safety. According to John King (personal communication, June 20, 2004), King Schools, Inc., a one order of magnitude improvement is not only needed but achievable. This improvement would virtually eliminate the primary cause of today's accidents—human factor errors. Current practice in aviation training has reached a plateau in the continuous improvements in general aviation safety. This plateau according to Wright (2002) is due to pilots continuing to make bad judgments. This study examines whether such bad judgments can be reduced and pilot decision-making can be further improved. The specific goals of the study were to evaluate the effectiveness of the FITS training to (a) improve judgment and decision-making skill, (b) improvement in automation management skills, and (c) improve situational awareness. The other goals of the study were to determine the difference between FITS and non-FITS training graduates and the specific strengths and weaknesses of FITS training.

This study examined a method of teaching higher order thinking skills (judgment and decision-making) and compared it to a self-study method and to the traditional method of instruction used in aviation education. That is, the study determined the difference between FITS and non-FITS trained graduates. It used a pretest-posttest control-group experimental research design to compare an example of a problem-based learning (PBL), a self-study, and non-PBL methods of instruction. In this study, the FITS training was the PBL and the non-FITS training were the self-study and non-PBL methods of instruction. The non-PBL methods of instruction were the maneuver-based methods of instruction used in current practice. The results of the experiment showed improvements in all measures and significant improvements in several measures of (a) judgment and decision-making skill, (b) automation management skills, and (c) situational awareness.

The specific strengths of FITS training are (a) the significant improvements in pilot performance, situational awareness, and aeronautical decision-making and (b) improvements in all measures. The FITS training displayed no weaknesses in the study when compared to non-FITS (maneuver-based training). The term pilot performance was used in the study instead of automation management skills because it was more inclusive of the skills needed by pilots. Likewise, the term aeronautical decision-making (ADM) is more inclusive than judgment and decision-making. ADM is the term most commonly used in general aviation to address judgment and decision-making skills and the training of those skills.

Additional research is needed to determine the value of this method for a wider population of pilots and for other aviation training. The improvements in aeronautical decision-making (judgment and decision-making) reported in the study are consistent with the finding reported in the mathematics and the medical fields. It is likely that the benefits found and reported in this study will occur in any aviation training application; however, this remains an imperial question until the additional research is conducted.

CHAPTER 1. INTRODUCTION

A. Purpose

The purpose of this document is to report the evaluation of the effectiveness of the FAA/Industry Training Standards (FITS) training philosophy, the metric developed to measure the effectiveness of the training, and to report the finding of evaluation. The evaluation metric included a metric to determine specific behavioral changes related to decision-making, judgment, and risk management and a metric to determine improvement or detriment of automation and task management skills. The specific goals of the study were to evaluate the effectiveness of the FITS training to (a) improve judgment and decision-making skill, (b) improvement in automation management skills, and (c) improve situational awareness. The other goals of the study were to determine the difference between FITS and non-FITS training graduates and the specific strengths and weaknesses of FITS training.

B. Introduction to the Study

1. The current practice in aviation training has resulted in an excellent aviation accident rate; however, according to Wright (2002), the continuous improvements in general aviation safety over nearly 25 years have reached a plateau. This plateau is due to pilots continuing to make bad judgments under certain circumstances. The study examined whether such bad judgments can be reduced and pilot decision-making can be further improved in general aviation, which is defined as all flying that is nonmilitary and not conducted by commercial airlines. The aviation community recognizes that at least one order of magnitude improvement in aviation safety is needed in general aviation (John King, personal communication, June 20, 2004). This improvement would significantly reduce the primary cause of the majority of today’s accidents. The study examined a method of teaching higher order thinking skills as a means to accomplish this order of magnitude improvement.

2. The educational approach used today in aviation education is based on (a) analyzing past accidents, (b) identifying accident trends, and (c) developing specific training to counter those trends, it does not adequately prepare pilots to handle atypical situations. Atypical situations are situations that the pilot has not been specifically trained to handle or situations that are first-time occurrences. These are the situations in which pilots are most likely to exercise bad judgment and make incorrect decisions. This educational approach to pilot training treats the symptoms and not the underlying cause, bad judgments. Current practices, based on past accidents, emphasize avoiding those common accidents. This approach does not teach pilots to handle new or unfamiliar problems. That is, training designed to eliminate a specific cause or deficiency only addresses the accidents that have occurred in sufficient numbers to be a significant cause and only those causes that have occurred before.

3. The *Aviation Instructor’s Handbook (AIH)* reports, “approximately 75% of all aviation accidents are human factors related” (1999, p. 9.8). Historically, these accidents were reported as pilot error, which meant an action, or decision made by the pilot was the cause of, or was a contributing factor, which led to, the accident (AIH, 1999). The problem is the continuing bad judgments. This study will determine if the problem lies in the pilot’s ability to use judgment, decision-making, and critical thinking skills to resolve problems when he or she has not been

specifically trained to handle that problem. Education needs to teach problem solving and the cognitive skills used in problem solving until they become automated and they become transferable to new situations or problems. That is, problem-solving skills must be taught and practiced until pilots develop the ability to solve ill-defined, ill-structured, complex problems. The common thread in the persisting aviation accidents is the absence of learning higher order thinking skills (HOTS). Teaching higher order thinking skills represents a significant departure from these safety initiatives previously implemented by the FAA to reduce aircraft accidents.

4. The literature shows that to teach HOTS effectively involves strategies and methods that emphasize analysis, synthesis, and evaluation. These strategies and methods include (a) using problem-based learning (PBL) instruction, (b) authentic problems, (d) real world problems, (e) student-centered learning, (f) active learning, (g) cooperative learning, and (h) customized instruction to meet the individual learner's needs (Carr, 1990; Cotton, 1991; Howe & Warren, 1989; Kerka, 1992; Reigeluth, 1999). Additionally, higher order thinking skills must be emphasized throughout a program of study for best results (Cotton, 1991). For aviation, this means HOTS should be taught in the initial pilot training program and in every subsequent pilot training program.

5. This study will discuss the strategies and methods for teaching HOTS as the means to enhance the development and transfer of these skills. It will evaluate two methods for instructing these skills to determine each method's effectiveness in improving pilot decision-making and in reducing the number of bad judgments. One method is a self-study approach similar to a typical aircraft delivery without factory training provided. The next method incorporates the strategies that emphasize HOTS in problem-based learning and the other used traditional aviation instructional methods. Traditional aviation instruction includes those methods recommended by the *Aviation Instructor's Handbook* (AIH) (1999), but do not specifically teach higher order thinking skills. Traditional aviation instructional methods are discussed in chapter 2.

C. Background of the Study

1. Currently, instruction in judgment training is called aeronautical decision-making (ADM) (Diehl, 1991). According to Advisory Circular 60-22 (AC60-22) (1991) and AIH (1999), "ADM is a systematic approach to the mental process used by aircraft pilots to consistently determine the best course of action in response to a given set of circumstances" (AIH, 1999, p. 9.8). The omission of cognitive skills from the definition used by aviation indicates that these skills are not included in ADM. The result of this absence of instructional guidance on cognitive skills in aviation is that HOTS are not being taught as effectively as they need to be to reduce the number of pilot-error type accidents.

2. Traditionally, the literature in aviation does not refer to teaching the development and transfer of cognitive skills (Bell & Mauro, 1999; Buch & Diehl, 1984; Deitch, 2001). However, a number of authors in aviation have begun to consider and analyze the value of teaching cognitive skills in addition to the cognitive process currently addressed in ADM training (Cohne & Freeman, 1996; Connolly, 1990; Jensen, 1988; Ryder & Redding, 1993; Shebilske, Regian, Winfred, & Jordan, 1992; Wiggins, 1997). The reports they have authored raise an important concern needs to be raised about why the current guidance and training materials do not reflect the need to teach cognitive skills. While it could be argued that higher order thinking is far more

complex than simply determining where to land the airplane, the underlying skills (analysis, synthesis, and evaluation) needed in making decisions are the same regardless of the complexity of the problem, and they are independent of the setting. The issue in aviation is whether pilot judgments can be improved by enhancing both the cognitive process and skills.

3. Modern learning theories underlie new teaching methods, which facilitate learning judgment, critical thinking, and decision-making. “Recent findings of cognitive research provide a better understanding of how people learn and how they solve problems, from which new teaching strategies are emerging” (Kerka, 1992, ¶ 1). A closer look at the teaching practices, methods, strategies, and techniques is necessary in order to understand how to adopt the strategies and methods to teaching HOTS in aviation. Additionally, a look is needed at the learning theories and instructional designs that support the development and transfer of HOTS. This study will investigate the changes that are needed in the current practices in aviation education to take advantage of the lessons learned from those disciplines already effectively using these new methods. Those disciplines successfully teaching HOTS include the medical field, philosophy, and creative writing.

4. Scenario-based training (SBT) is an example of problem-based learning (PBL) instructional methods that are being used in other disciplines to facilitate the enhancement of learning and the development and transference of thinking skills. Scenario-based training also provides an excellent example of how current practices in aviation education need to be changed. The SBT currently being used in aviation may more appropriately be called situated training. The scenario simply describes the situation or setting within which a stimulus will be introduced and the student is expected to respond with a “canned” response. Current aviation practice is a stimulus/response learning approach. The situation, a system malfunction or failure, is the stimulus and the response is the execution of the established procedure. This situation is described as a scenario. The situation, a system malfunctiobn or failure, is the stimulus and the response is the execution of the established procedure. The authors of the AIH (1999) describe the situation as a scenario. The AIH (1999) prescribes the stimulus/response learning model for teaching pilots how to handle abnormal and emergency procedures is the typical teaching approach. In this case, scenarios are simply used as a means to set the situation or conditions within which a malfunction occurs. Handling these situations requires the implementation of established procedure. This use of scenarios does not draw the pilot into formulating possible solutions, evaluating the possible solutions, deciding on a solution, judging the appropriateness of that decision and finally, reflecting on the mental process used in solving the problem. It does not cause the pilot to consider whether the decision led to the best possible outcome or challenge the pilot to consider other solutions. The current limited application of SBT is used in ways that are not focused on HOTS, but rather on conditioned responses, that requires little by way of thoughtful decision-making. Thoughtful decision-making and reflective thinking are essential in developing HOTS. SBT is discussed in more detail in chapter 2, but it is the thoughtful and reflective version of SBT this study is seeking to evaluate.

5. The FAA recognizes that training in atypical situations is inadequate. “Traditionally, pilots have been well trained to react to emergencies, but are not as well prepared to make decisions which require a more reflective response” (AIH, 1999, p. 9.10). A more reflective response would apply to a situation where there are (a) multiple solutions, (b) no single best answer, (c) no matches to previous experiences, (d) no easy solution, or (e) no “canned” procedure already

established. Reflective responses apply to situations that are ill-defined, ill-structured, complex problems. Teaching pilots to make better reflective responses is the focus of the instructional method evaluated in this study.

6. The development of the ability to solve ill-defined, ill-structured, complex problems must be taught and practiced. Scenario-based training including reflective thinking is an example of an instructional method that supports the development of the underlying cognitive skills pilots need to make better judgments and decisions. Air carriers began their effort to improve pilots' judgment and decision-making skills in the early 1980s when they introduced crew resource management (Helmreich & Foushee, 1993). As CRM training evolved, air carriers began to use line orientated flight training (LOFT) as a means to bring the components of CRM training together in a simulated flight. The scenario is a simulated flight typically conducted in a full-motion flight simulator that follows one of the actual routes the air carrier flies in normal, scheduled service.

7. Primarily, CRM and LOFT focus on improving teamwork in the cockpit to make the best use of the existing skills, personnel, and information; that is, effective use of all available resources (Advisory Circular 120-51E [AC120-51E], 2004). Line-oriented flight training (LOFT) has proven effective in moving CRM training from the theoretical classroom discussion to practical applications of CRM concepts (Orlady & Orlady, 1999). Like CRM, LOFT training is specifically designed to combine the crew's collective abilities in solving problems. According to the authors of AC120-51E (2004), CRM and LOFT training focus on improving pilot/crew decisions by making better use of existing decision-making skills rather than improving the decision-making skills of each pilot. CRM and LOFT training again treat the symptoms not the cause, that is, they do not teach the thinking skills a pilot needs to develop in order to make good decisions. CRM and LOFT training is geared toward aircrews, multi-pilot operations, not the single-pilot. Single-pilot operations are typical in general aviation. While both of these aircrew training programs show the potential benefit of the simplest form of scenario-based learning in aviation, neither program specifically addresses HOTS and neither program is available to the general aviation pilot.

8. This study focused on transition pilot training. Typically, this transition training is either a part of the pilot's initial pilot training experience or follows his or her private or private and instrument training. Initial pilot training often takes an individual only to the level of earning a single-engine airplane private pilot certificate. This allows the individual to fly a single-engine airplane and carry passengers. It does not allow the individual to carry passengers or cargo for compensation or hire. Additional certificates and ratings are required to operate the airplane when carrying passengers or cargo for compensation or hire. Initial flight training and the additional certificates and ratings for instrument and commercial operations are typically conducted in general aviation. These additional certificates and ratings involve all types of flight operations including private, business, corporate, and airline. Thus, the potential impact of these improvements in training would not be limited to general aviation.

9. General aviation has arrived at a critical juncture in its development and it is on the threshold of providing significant service to the traveling public. The development of technically advanced aircraft (TAA) is propelling general aviation into becoming a viable, effective and efficient, means of air transportation. General aviation is becoming an alternative to traveling on an

airliner. Currently, general aviation has the highest fatal-accident rate of all of the sectors of aviation. Thus, general aviation is the area with the most urgent need for improvement.

10. The FAA has implemented several safety initiatives to improve the general aviation fatal-accident rate because they are responsible for the protection of the traveling public. In 1995, the FAA Administrator commissioned a study, Challenge 2000, which concluded

> A new system safety model is needed to replace the existing one built on regulations, certification, inspection, surveillance, and enforcement… The report postulated that the current system of minimum standards was outmoded and recommended more reliance on industry “best practices” as a means to achieve higher levels of safety. (Wright, 2002, p. 6)

11. The System Safety Approach for General Aviation (SAGA) initiative focused its approach on risk management/aeronautical decision-making, education and training, and appropriate use of new flight technologies to achieve higher safety levels. Another major safety initiative begun recently is called the Safer Skies program; it focused on weather, controlled flight into terrain (CFIT), aeronautical decision-making, runway incursions, approach and landing, loss of control, and survivability. The Safer Skies program, a joint FAA/industry initiative based on extensive data analysis, targeted those safety issues that will most likely lead to a fatal accident and their causalities. Once the safety issues were identified, the FAA implemented another joint initiative involving industry and academia in a proactive approach to reducing the general aviation fatal accident rate called the FAA/Industry Training Standards (FITS) initiative.

12. This latest effort is focused on resolving the underlying problems rather than the targeted safety issues identified in the analysis of the aviation accident databases, which include the airline, business, corporate, and general aviation. FITS has adopted a draft mission statement that says, “To improve pilot learning to ensure pilots are able to safely, competently, and efficiently operate technically advanced aircraft in the modern National Airspace System by integrating higher order thinking skills instruction and implementing scenario-based flight training” (*“FITS” Master Instructor Syllabus: TAA Scenario Based Instructor Guide*, 2003, p. 2). The FITS mission statement clearly indicates a need to teach HOTS.

D. Statement of the Problem

1. Pilots in today’s aviation education programs are not being adequately taught the necessary higher order thinking skills required to continue the progress in improving aviation or to eliminate the persistent pilot-error type accidents in general aviation. According to the General Aviation Joint Steering Committee, the leading causes of accidents in general aviation are (a) controlled flight into terrain (CFIT), (b) weather, (c) runway incursions, (d) pilot decision-making, and (e) loss of control; typically, these causes are referred to as pilot-error or human factors related type accidents. CFIT, runway incursions, and loss of control type accidents typically occur when the pilot makes a series of bad judgments, which leads to these events. For example, when the pilot has not adequately planned the flight and the pilot has subsequently fails to maintain adequate situational awareness to avoid the terrain, a CFIT accident occurs. Often the loss of control occurs when the pilot exceeds design or established operating standards, and the resulting situation exceeds the pilot capability to handle it successfully. The FAA and the

aviation instructor community generally accept these occurrences as resulting from bad judgment. Likewise, most weather-related accidents are not a result of the weather per se but rather a failure of the pilot to avoid a weather phenomenon that the aircraft is not equipped to handle or the pilot is not trained to handle. That is, the pilot decides to fly or to continue into weather that the pilot should not attempt to fly in, again commonly considered bad judgment (Orlady & Orlady, 1999).

2. To correct or improve general aviation safety and to reduce pilot-error type accidents by 20% by 2007, a goal established for general aviation in the Safer Skies initiative, aviation education and flight training programs must improve pilot learning in higher order thinking skills or in someway reduce bad judgments. This investigation is to determine if the methods and strategies for teaching HOTS in other disciplines are effective and efficient in aviation education. Subsequently, the aviation instructor community will need to draw on good teaching practices, proven techniques, and the tools used in other disciplines to meet the learning needs of aviation. They will also need to develop the curriculum and instructional material that enhance the development and transfer of higher order thinking skills.

E. Purpose of the Study

The purpose of the study is to determine if FITS is better than maneuver-based training in developing aeronautical decision-making (judgment and decision-making). FITS includes several methods of instruction based on problem-based learning (PBL). Therefore, this study is to determine if PBL provided through blended instruction significantly enhances the development and transfer of higher order thinking skills and the quality of pilot judgments in aviation education. This study will examine a blended approach to instruction including online instruction delivered on a computer by way of a CD-ROM, DVD-ROM, Internet, or intranet. The study will compare the effects of two methods of instruction and a self-study group on college students' aeronautical decision-making to determine if one of the methods is more effective and efficient in aviation education. The two methods of instruction will involve (a) classroom and online PBL methods of instruction and scenario-based flight instruction, and (b) classroom and online non-PBL methods of instruction and maneuver-based flight instruction; while, the self-study group received no instruction and equal practice time.

F. Rationale

The fundamental reasons for this study are to (a) determine if using blended instruction that incorporates problem-based learning is effective and efficient in enhancing the development and transfer of higher order thinking skills (HOTS) in aviation education, and (b) determine if the improvement in HOTS results in enhancing aeronautical decision-making and pilot judgments during normal, abnormal, and emergency situations.

G. Research Questions/Hypothesis

The research questions that will be answered in this study are (a) What is the effect of the method of instruction on upper-division college students' development and transfer of higher order thinking skills, and (b) does problem-based instruction increase pilot judgments and performance compared to instruction that is not problem based? In this study, the college students hold commercial single- and multi-engine certificates with an instrument rating. To answer these questions, an experimental research design will be used to examine the effects of the method of instruction on decision-making using blended methods with PBL and without PBL. The hypothesis is that PBL offered in blended instruction will significantly improve higher order thinking and aeronautical decision-making skills and significantly reduce bad judgments.

H. Significance of the Study

Knowing how to enhance learning with technology is not enough; educators must know whether a particular method of instruction effectively meets the specific instructional needs of the learners. Researchers must identify and test tools, practices, procedures, and methods before offering them as possible solutions for enhancing performance improvement or in this case for reducing the bad judgments made by pilots. This study is a necessary step in seeking to improve general aviation safety because it will help identify an effective method of instruction that will enhance the development and transfer of higher order thinking skills in pilots.

I. Definition of Terms

Some of the terms used in this study have unique meaning in aviation, or lack a universally accepted meaning; therefore, they will be defined in this section to facilitate a better understanding of the material presented in this study.

Advanced Training Device. An advanced training device (ATD) was formerly referred to as a personal computer-based advanced training device (PC-ATD), which is more descriptive; nevertheless, the correct term is now an ATD. ATD is a flight simulation program operating on a personal computer. The ATD used in this study is based on MS Flight Simulator 2004. MS Flight Simulator 2004 can be certified, in fact, by the FAA as an ATD. This allows up to 10 hours of ATD flying time to be logged toward the minimum flight experience required by FAA for a pilot certificate or rating. The ATD affords all of the advantages normally provided in instructional simulations, without the cost or risk of actually flying the aircraft.

The ATD used in this study is a prototype of a new product being developed to meet the pilot training needs of technically advanced aircraft (TAA). General aviation is following the lead of the airline industry and rapidly moving toward modernizing cockpit displays including the replacement of basic pilot instruments with a single screen-type primary flight display (PFD), a global navigation system (GPS) with a moving map, and a multifunctional display (MFD). These new instruments require pilots to use different skills than the ones they used with the instruments they replaced. This new produce is being designed to meet these training needs.

Aviation Education. This study will only address the type of pilot training offered in a physical classroom environment because, according to Kent Lovelace (2003, personal communication), there are no aviation education programs offering flight training in a distance education setting. In this case, aviation education is defined as a baccalaureate degree that includes classroom, flight laboratory (flight training), and professional experiences courses, according to CAA101 (1990). The issues in this study are the challenges to learning that occur in an academic classroom setting. The typical academic setting involves large class sizes and multiple instructors for the various courses (topics) while the pilot licensing setting commonly involves one-on-one instruction and a single instructor. This means the method of instruction must be changed to accommodate the lack of individual instruction and loss of continuity of training occurring in the academic setting. Both conditions present instructional challenges, which exacerbate the instructional problems mentioned at the beginning of this paper, which involves teaching pilots how to make good decisions.

Crew Resource Management. Crew resource management (CRM) is the application of team management concepts in the flight deck environment. This includes single pilots, as in most general aviation aircraft. Pilots of small aircraft, as well as crews of larger aircraft, must make effective use of all available resources: human resources, hardware, and information. A current definition includes all groups routinely working with the cockpit crew who are involved in decisions required to operate a flight safely. These groups include, but are not limited to, pilots, dispatchers, cabin crewmembers, maintenance personnel, and air traffic controllers. CRM is one way of addressing the challenge of optimizing the human/machine interface and accompanying interpersonal activities. A variation on CRM, single pilot resource management (SRM) has recently been introduced to address the issues in single pilot and general aviation operations.

General Aviation. General aviation was loosely defined earlier to introduce this study. A more complete definition follows. There is no official definition of general aviation, but it is commonly described as “all civil aviation except that carried out by the commercial airlines” (Wells & Wensveen, 2004, p. 134). General aviation is the largest segment of aviation based on the number of aircraft, pilots, airports, and communities served—it includes over 91% of the civil air fleet, 75% of civil operations at FAA-towered and non-towered airports, and 80% of the total certificated pilots in the United States (Wells & Wensveen, 2004). The FAA officially categorizes general aviation operations by primary-use. Primary-use categories include corporate, business, personal, instructional, aerial application, aerial observation, sightseeing, external load, air tour, air taxi, medical, and other. These primary-uses involve aerial application planes that treat one out of every five tillable acres of land, the land developer making survey flights and the police officer observing traffic, the family on a vacation trip, and the air ambulance flying a mercy mission (Wells & Wensveen, 2004). The other category includes weather modification flights (cloud seeding); sales demonstration flights; power line and pipeline patrol flights; and research and development, testing, and various government flights.

Higher Order Thinking Skills . It is generally accepted that higher order thinking skills are the cognitive process and cognitive skills involved in making a rational decision on what to do or what to believe (Ennis, 2000; *What is Higher Order Thinking*, n.d.). Yet, according to Cotton (1991), there is no universally accepted definition of higher order thinking, creative thinking, critical thinking, or decision-making. Thomas and Albee (1998) asserted that “critical/creative/constructive thinking is closely related to higher order thinking: they are actually inseparable” (*What is Higher order Thinking*, ¶ 9). Alvino (1990) offered a “Glossary of Thinking-Skills Terms” which “are widely—though not universally—accepted by theorists and program developers. Bloom’s Taxonomy –

categorizes thinking skills from the concrete to the abstract—knowledge, comprehension, application, analysis, synthesis, and evaluation. The last three are considered higher order skills.” Thus, in this study, HOTS are analysis, synthesis, and evaluation skills (Alvino, 1990; Cotton, 1991; Reigeluth & Moore, 1990).

Instructional Design Theory. Instructional design theories describe how to facilitate learning (that is, methods of instruction) (Reigeluth, 1999). An instructional design theory based on the information processing learning theory would describe how the instructional activities would facilitate learning and how to facilitate learning using the senses to collect and interpret the information for storage in STM. Instructional design theories and methods facilitate the learning process that the learning theory described. Selecting an appropriate instructional design will depend on the specific learning requirements, in teaching judgment, both the cognitive process and cognitive skills needed to make solid aeronautical decisions.

Judgment. Judgment is the mental process of recognizing and analyzing all pertinent information in a particular situation, a rational evaluation of alternative actions in response to it, and a timely decision on which action to take.

Learning Theory. For the purposes of this study, learning theories describe how learning occurs (Reigeluth, 1999). For instance, the information processing theory is a learning theory that describes learning as a process similar to how a computer processes information. The information is received in short-term memory (STM) from the senses, and then it is encoded and stored in long-term memory (LTM). When the information is subsequently needed, it is retrieved from LTM and decoded into STM.

Pilot Error. Pilot error is a bad judgment or bad decision. “Pilot error means that an action or decision made by the pilot was the cause of, or [was a] contributing factor which led to, the accident” (AIH, 1999, p. 9.8). Currently, these accidents are reported as human-factor related because accidents seldom occur as the result of a single pilot error but rather occur after a series of bad judgments. In this study, the term pilot error will be used to describe the bad judgments made by pilots. Pilot errors are the most critical instructional challenge facing the aviation community. Formally, pilot error was identified as the causes of or a contributing factor in approximately 75% of the general aviation accidents.

Poor Judgment Chain. Poor judgment chain is a series of mistakes that may lead to an accident or incident. Two basic principles generally associated with the creation of a poor judgment chain are (1) one bad decision often leads to another; and (2) as a string of bad decisions grows, it reduces the number of subsequent alternatives for continued safe flight. The intent of ADM is to break the poor judgment chain before it can cause an accident or incident.

Situational Awareness. Situational awareness is the accurate perception and understanding of all the factors and conditions within the four fundamental risk elements that affect safety before, during, and after the flight.

Technically Advanced Aircraft. According to the authors of the FITS master instructor syllabus, TAA instructor guide, a technically advanced aircraft (TAA) is “a general aviation aircraft that combines some or all of the following design features: advanced cockpit automation system (Moving Map GPS/ Glass Cockpit) for IFR/VFR flight operations, automated engine and systems management, and integrated auto flight/autopilot systems” (2003, p. 3). The moving map is an electronic map of the area surrounding the actual location of the aircraft displayed on a cathode ray tube (CRT) or liquid crystal display (LCD). The display provides the pilot with a visual representation of the aircraft’s position and with information for navigation. The pilot is also commonly provided with an electronic representation of the flight and aircraft performance instruments. They are the glass cockpit. The modern cockpit is designed to provide significantly more useful information to the pilot and to provide enhanced situational awareness. Situational awareness was defined earlier.

J. Assumptions and Limitations

1. It appears reasonable to assume that the strategies and methods used to teach cognitive skills in other fields would be effective in aviation; therefore, teaching these skills should improve the pilot’s ability to make good judgments and subsequently result in improving the accident rate. The cognitive skills needed in making decisions and judgments, HOTS, can be taught like any other cognitive skill. HOTS should be taught throughout the curriculum from simple to complex and from concrete to abstract. Instructional designs based on cognitive and constructive learning theories will provide the best instruction for the development and transfer of HOTS. These instructional designs will need to include receptive, directive, guided discovery, and exploratory approaches using PBL instruction incorporating authentic and real world problems; furthermore, the instruction will need to be student-centered, active, and include cooperative learning.

2. Poor higher order thinking skills, lack of development of HOTS, or inadequate practice of problem solving to facilitate transference are the underlying cause of pilot bad judgments and decisions, which result in pilot-error type aviation accidents. Enhancing the development and transfer of higher order thinking skills will lead to fewer pilot judgment errors. When HOTS are effectively taught in aviation, pilot judgment and decisions should improve. Teaching pilots HOTS should better prepare pilots to handle new or different situations in other words, situations they have not seen or experienced before. The current accident rate indicates that most, if not all, aviation education and flight-training programs inadequately teach judgment and decision-making, particularly to the new training standards being established by the FAA for technically advanced aircraft operating in the modern airspace system.

3. Limitations in this study include the selected population, sample size, advanced training device, performance test, and measurement instruments. The population that will be used in the study is upper-division college students majoring in aviation or aviation related degrees; thus, it may not be typical of other learner groups or pilot populations. As a minimum requirement, these students will be required to have a commercial single- and multi-engine pilot certificate and an instrument rating. The FAA allows individuals to obtain the student pilot certificate, in some cases, as low as 14 years old and does not have a termination date; thus, the pilot population is 14 or older. The educational background of the general pilot population is quite varied because

there is not educational requirement. A more detailed description of the subject participating in the study will be presented in chapter 3.

4. The sample size is considered an important limitation in this study. The general pilot population consists of more than 700,000, according to the FAA. Findings based on the small number of participants that is to be used in this study cannot be generalized to the general pilot population but should be meaningful in determining if PBL has the potential to improve aeronautical decision making, and if it is worthy of additional research.

5. The advanced training device is listed as a limitation because it is a prototype device and it is still under development. This means that there is a risk that the device may experience technical difficulties or other problems. This also means that the experiment cannot be duplicated outside of the experiment until the production device becomes available or a similar device can be constructed. Finally, not every feature of the TAA is simulated exactly. With the exception of experiencing unexpected technical difficulties, none of these should affect the results and findings.

6. Pilot performance testing is not completely objective. The FAA has established and published a well-structured set of standards for conducting a pilot performance test. These standards include specific heading, altitude, and airspeed criteria as well as smoothness and aircraft mastery guidance. Nevertheless, some degree of subjectivity remains in performance testing and differences between evaluators exist. This subjectivity and these differences are recognized and accepted by the individuals choosing to become and remain pilots. This is a limitation in this study.

7. The pretest and posttest were adapted from previous studies. They include an aeronautical decision-making and a pilot performance assessment. The validity and reliability of the tests for measuring aeronautical decision-making are not widely accepted and need additional and independent validation. Validity and reliability will be addressed in more detail later; however, they are recognized as limitations at the onset. Decision-making skills will be evaluated against existing FAA performance criteria. Again, the FAA performance criteria are contained in a set of practical test standards established for each pilot and instructor certificate or rating.

K. Organization of the Remainder of the Study

The study will follow a five-chapter format. A literature review will follow this chapter and begin with an introduction. Next, it will examine (a) the applicability of teaching HOTS to enhance the development and transfer of pilot decision-making skills, (b) strategies and techniques for teaching HOTS, (c) instructional designs that support the strategies, techniques, and teaching methods, and (d) learning theory underlying HOTS development and transfer. The third chapter explains the methodology the study employed. An experimental research design was used to test the cause/effect relationship between different methods of instruction and their effectiveness in achieving development and transfer of aeronautical decision-making skills. The research design, data collection, and data analysis including the pretest and posttest instruments for measuring decision-making skills and pilot performance are discussed in chapter three. The analysis of the data and findings, results, and conclusions are presented in the last two chapters.

CHAPTER 2. LITERATURE REVIEW

A. The literature review will provide the theoretical basis and serve as the foundation of this study. It provides guidance on how this study should be conducted to answer the research questions asked in the first chapter. It establishes the connections among the problem, the proposed solution to the problem, and the instructional methods suggested to achieve the solution. The literature review will be divided into seven sections addressing (a) the enhancement of pilot decision-making including the requirements for teaching higher order thinking skills (HOTS); (b) learning theories supporting the development and transfer of HOTS; (c) instructional designs supporting HOTS; (d) theoretical underpinnings of instructional design including type of, control of, focus of, grouping for, interactions for and support for learning; (e) practical applications and relevance to aviation education; and (f) online aviation education including key research in online instruction, current practices, and how online instruction supports good teaching practices. The final section will summarize the key literature presented in this chapter.

B. Enhancing Pilot Decision-Making

1. Higher order thinking skills (HOTS) including analysis, synthesis, and evaluation describe both the cognitive process and cognitive skills that are essential to judgment, decision-making, and critical thinking. Teaching HOTS is, actually, the same thing referred to as aeronautical decision-making in aviation. They are taught like other cognitive skill, that is, from simple to complex and from concrete to abstract. HOTS are all learned in a similar fashion and are supported by the same learning theories that facilitate their development and transference. Thus, they will be addressed as a unit and not individually in the review. This review will begin by identifying the requirements for teaching HOTS.

2. Requirements for Teaching Thinking Skills

(1) The requirement for teaching HOTS can be identified by examining the teaching methods and strategies used in disciplines outside of aviation, for instance the medical field. However, Cotton (1991) said, “There is no one best way to teach thinking skills” (Programs, Strategies, and Training are Important section, ¶3). Instruction in many specific skills and techniques using various instructional approaches to promote the development and enhancement of thinking skills is supported in the research (Peirce, 2001; Splitter, 1995). To foster the development of thinking skills, the instruction should include redirection/probing/reinforcement, asking higher order questions, and lengthening wait-time (Cotton, 1991). Cotton (1991) drew these conclusions after reviewing 56 documents, including 33 reports of research studies or reviews of which 23 were descriptive, theoretical, or guideline documents, or the studies concerned with research in areas other than the effectiveness of programs and practices. The implication from these papers is that any strategy or technique employed to facilitate learning thinking skills can be effective, if properly administered. These strategies involve engaging the learner in some form of mental activity, having the learner examine that mental activity, selecting the best solution, and challenging the learner to explore other ways to accomplish the task or the problem (Landa, 1999).

(2) In contrast to the guidance provided above for teaching HOTS, the current guidance for aviation omits any discussion or guidance for the development and transfer of the necessary cognitive skills to support learning judgment and decision-making. Instead, the AIH (1999) emphasizes learning a decision process which it refers to as the “DECIDE” model, that is, (a) detect—the fact that a change has occurred, (b) estimate—the need to counter or react to the change, (c) choose—a desirable outcome for the success of the flight, (d) identify—actions which could successfully control the change, (e) do—the necessary action to adapt to the change, and (f) evaluate—the effect of the action. According to the authors of the AIH (1999), “a problem is perceived first by the senses, then is distinguished through insight and experience” (p. 9.11). This implies that the cognitive skills needed in ADM are either innate or learned through experience, that is, they are not taught or learned through the instruction normally provided in the aviation education or flight training programs.

(3) The authors of the AIH say, “the best way to illustrate this [poor judgment chain] concept is to discuss specific situations which lead to aircraft accidents or incidents…a scenario which can be presented to students to illustrate the poor judgment chain” (1999, p. 9.8). “By discussing the events that led to this incident, instructors can help students understand how a series of judgmental errors contributed to the final outcome of this flight” (AIH, 1999, p. 9.9). According to the authors of the AIH (1999), “ADM training focuses on the decision-making process and the factors that affect a pilot’s ability to make effective choices” (p. 9.9). It could be argued that the scenarios presented by the instructor would provide the pilot with an example of how to solve a problem, and this example could be recalled later to decide what he or she should do to break a similar poor judgment chain. However, it does not teach the pilot how to handle dissimilar or new error chains. This difference between these two strategies is that Landa’s (1999) approach actively engages the learner in mental activities, examinations, and evaluations, while the AIH (1999) directs the instructor to illustrate the poor judgment chain so the pilot understands the mental process as a passive learner. Because Landa’s (1999) approach engages the learner in active learning, his approach should enhance the learning process. This is the critical difference between teaching judgment in aviation and elsewhere.

(4) In aviation, many scenarios are presented to the student pilot as worked examples, demonstrating how the expert would solve a problem or a series of problems. Outside of aviation, this approach may be referred to as a case study. A difference will also occur when the instruction outside of aviation includes instruction and practice in applying these techniques to new situations, in other words, teaching the learner to transfer the knowledge from one problem to other problems. Transferring problem solving skills from one problem to another assumes the supporting cognitive skills (analysis, synthesis, and evaluation) have been or are being developed.

(5) Teaching higher order thinking skills effectively involves customizing the examination and exploration of the mental activity to meet the individual learning needs. Kerka (1992) said:

> Learning is characterized as an active process in which the learner constructs knowledge because of interaction with the physical and social environment.

> Learning is moving from basic skills and pure facts to linking new information with prior knowledge; from relying on a single authority to recognizing multiple sources of knowledge; from novice-like to expert-like problem solving[(Thomas, 1992)]. (*What Strategies Develop These Skills*, ¶ 1)

Howe and Warren (1989) added, “there needs to be a shift in many classes, from a teacher-centered classroom to a student-centered classroom in which students can be involved in collecting and analyzing information, paired problem solving, cooperative learning settings, simulations, debates, and critical reporting sessions” (What Does Research Indicate Regarding Teaching Critical Thinking section, ¶ 6). In addition to the approaches offered above, Landa (1999) said, three strategies can be used to facilitate the learning of thinking skills; they are guided discovery, expository teaching, and a combination strategy. Landa (1999) described the guided discovery strategy as (a) giving the learners a task or problem and having them perform it, (b) helping the learners formulate a method (detailed set of instructions) to follow to perform the task, (c) having the learners examine the mental activity, and (d) then challenging them to explore other ways to accomplish the task or the problem. Teaching HOTS effectively involves emphasizing HOTS strategies in PBL which includes problem solving-, case study-, and scenario-based instruction (Reigeluth, 1999). Cotton (1991) said, “Educators are now generally agreed that it is in fact possible to increase students’ creative and critical thinking capacities through instruction and practice” (Introduction section, ¶ 9). Ristow (1988) and Presseisen (1986) reiterate, students can learn HOTS, if schools will concentrate on teaching them how to do so.

(6) Before the learning theories are examined, the requirements for facilitating the transfer of HOTS from the instructional setting to their application should also be discussed. Transfer of knowledge relates to learning and storing information in long-term memory (LTM) and then retrieving or recalling that information from LTM to some application of that information or knowledge. The information involves declarative knowledge (knowledge about things) and procedural knowledge (knowledge about how to do things) (Clark, 1999). In the learning setting, it is critical to avoid inert knowledge, that is, knowledge that is learned and cannot be recalled later in a different setting.

(7) Avoiding inert knowledge often involves relating information to the environment where the information or knowledge is to be applied. Knowledge transfer may fall into either near- or far-transference (Alessi & Trollip, 2001; Clark, 1999). Transference does not depend on the instructional model but rather on the nature of the problem, scenario, or case presented and its relevance to the environment or setting where it is to be applied. Developing authentic and realistic problems in the learning setting with very similar circumstances to those occurring in aviation, for example, will promote near-transfer. Near-transfer teaching methods include practicing or drilling systematic procedures. These methods may be used because there is little variance in the application of the procedure. In contrast, far-transfer teaching methods may be needed in other situations including abnormal or emergency, particularly when ill-structured, ill-defined, complex problems are involved and where the pilot must use extensive judgment, must use a different approach, or there are no set steps or set procedures established to solve the problem. According to Clark (1999), “use schema-based instructional models to teach

far-transfer tasks including problem solving tasks that (a) use a schema-based training design, (b) provide varied context examples and problems, and (c) teach related process knowledge" (p. 103). The learning requirements discussed above about teaching HOTS are addressing the near- and far-transference challenges in learning. The transference of knowledge from the learning environment to some application of the knowledge is not a separate problem; it is the problem addressed in the literature on teaching HOTS.

3. Learning Theories Supporting the Development of HOTS

(1) Now that the relationship and requirements side of the teaching issue have been addressed, it is time to consider how HOTS are learned. In other words, what learning theories explain and support how higher order thinking skills are learned? This is important because for teaching methods to be effective they must be based on learning theory (Alessi & Trollip, 2001; Carnegie, 2002; Reigeluth, 1999). After a brief overview of the behavioral, cognitive, and constructivist learning principles, their ability to support the requirements of teaching HOTS will be discussed. Alessi and Trollip (2001) said, "No universal agreement exists on how learning occurs. How psychologists have viewed the principles of learning has changed significantly throughout the 20th century" (p. 16). Driscoll (2000) said:

> Despite the differences among the learning theories … they do share some basic, definitional assumptions about learning. First, they refer to learning as a persisting change in human performance or performance potential. This means that learners are capable of actions they could not perform before learning occurred and this is true whether or not they actually have an opportunity to exhibit the newly acquired performance … Second, to be considered learning, a change in performance or performance potential must come about as a result of the learner's experience and interaction with the world. (p. 11)

(2) The persisting change in human performance or performance potential resulting from the learner's experience and interaction with the world can be explained by behavior, cognitive, or constructivist learning theories or a combination of these theories or by one or more of the specific learning theories within these theories.

(3) Behavioral Learning Theory.

(a) Behaviorism appears to have been built on the foundation begun by Ebbinghaus' verbal learning experiments and the work of Pavlov and Thorndike (Driscoll, 2000). In fact, according to Driscoll (2000), Ebbinghaus is credited with ushering in a new era of interest in the study of learning, when he began experimenting with the notion that if ideas are connected by the frequency of their association, then learning should be predictable. Thorndike, on the other hand, believed sensation and impulse, rather than idea association was important. This led Thorndike to propose the Law of Effect. Meanwhile, Pavlov's experiments led to classical conditioning. These early works formed the groundwork for B.F. Skinner's radical behaviorism. Skinner's work refined and demonstrated that a particular pattern of reinforcement or punishment resulted in different rates of learning or degrees of retention, based on the principle of

association, Law of Effect, classical conditioning, and operant conditioning. Central to this theme is the belief that learning is always an observable change of behavior and it is a result of connecting certain responses with a given stimuli (Alessi & Trollip, 2001; Behaviorism, 2000; Carbenell, 2001; Huitt, 1997; Murphy, 1997; *Operant Conditioning*, n.d.; *Operant Conditioning*, 1996).

(b) The behaviorist learning theory "maintains that learning should be described as changes in the observable behavior of a learner made as a function of events in the environment" (Alessi & Trollip, 2001), and it includes Pavlov's classical conditioning. According to Alessi and Trollip (2001):

> The basic principle of classical conditioning is that repeatedly pairing a neutral stimulus with a natural stimulus (one that elicits a natural response) causes the neutral stimulus also to elicit the response. The implication is that humans learn many behaviors because of their pairing with basic human needs and responses, such as the need for food, sleep, reproduction, and the like. (p. 18)

(c) When classical conditioning is coupled with operant conditioning, the use of rewards and punishments, the behavior modification can be more efficient and effective. Criticism of this approach argued it ignores important unobservable aspects of learning (such as thinking, reflection, memory, and motivation) (Alessi & Trollip, 2001).

> Decades of learning research have demonstrated that classical and operant conditioning principles do not predict all learning outcomes. Theories of motivation, memory, transfer, and the like have promoted instructional methods that behavioral techniques would not… The outcomes of education and training must include more than just learner achievement. They must include learner satisfaction, self-worth, creativity, and social values… People must be adaptive and lifelong learners, must have the confidence necessary to change with their environment, and must be able to work collaboratively with others… These goals are values that were marginally recognized by behavioral approaches to education… Behavioral principles such as positive reinforcement, corrective feedback, and spaced practice are appropriate in interactive [settings]. (Alessi & Trollip, 2001, pp. 36-37)

(d) Traditionally, the behavioral principles have been used to explain how aviators learn various flight procedures including responses to changing flight conditions, normal, abnormal, and emergency situations (AIH, 1999). However, it appears the behavioral principles do little to support the learning requirements of the cognitive skills element of higher order thinking. When the cognitive process only is considered, behavioral principles support the procedures that are carried out as a response to a stimulus. In fact, most of the current training in aviation involves aeronautical and procedures knowledge (cognitive processes), training methods rely heavily on behavioral principles with extensive use of positive reinforcement, corrective feedback, and spaced practice (AIH, 1999). While many normal, common abnormal, and common emergency situations can be taught and practiced effectively, many atypical abnormal and emergency situations are not anticipated; thus, they are not taught. The aviator is required to employ cognitive skills in many situations where he or she was not specifically trained and may not have prior experience. Understandably, behavioral principles do little to explain how these cognitive skills are learned when either unanticipated or multiple responses are required, in other words, when the pilot is faced with an unknown or an ill-defined, ill-structured, complex problem.

(e) Behavioral principles also do not adequately address the transfer of learning problems occurring between the training setting and the application of decision-making skills. Behavioral principles could produce knowledge that can be applied in near-transference situations; in fact, normal and some abnormal and emergency procedures have been taught effectively for years where an identifiable stimulus (system malfunction) resulted in a need to apply a set procedural response. However, since extensive judgment and problem-solving skills are not observable behavior, when far-transference is needed, the behavioral principles do not support this type of transference. HOTS require unobservable behavior changes and cognitive learning not supported by the behavioral learning theory.

(4) *Cognitive Learning Theory*.

(a) In contrast to the behaviorist view that learning affects observable behavior only, cognitive learning theory involves the mental processes of learning (Alessi & Trollip, 2001; *Cognitive Learning Theory*, n.d.; *Cognitive Learning Theory Terms*, n.d.; *Information Processing Theory*, 1996). According to Driscoll (2000),

> In the cognitive information processing view, the human learner is conceived to be a processor of information in much the same way a computer is. When learning occurs, information is input from the environment, processed and stored in memory, and output in the form of some learned capability. (p. 76)

(b) The cognitive learning theory addresses the process occurring inside the learner's mind and the internal processes of learning (Reigeluth & Moore, 1999; Alessi & Trollip, 2001). According to Alessi and Trollip (2001), "cognitive psychology places emphasis on unobservable constructs, such as the mind, memory, attitudes, motivation, thinking, reflection, and other presumed internal processes" (p. 19). Cognitive learning is dominated by the information-processing approach (Alessi & Trollip, 2001). "The areas of cognitive theory that are most important to [instructional] design are those relating to perception and attention, encoding of information, memory, comprehension, active learning, motivation, focus of control, mental models, metacognition, transfer of learning, and individual differences (Anderson, 1980; 1981; Anderson, 1977; Berger, Pezdek & Banks, 1986; Bower & Hilgard, 1981; Gagné, Yekovich, & Yekovich, 1993; Kozma, 1987)" (Alessi & Trollip, 2001, p. 20). Conversely, "the cognitive approach has undervalued the powerful principles of reinforcement. Cognitive educators spoke of collaboration, communication, and transfer … [But] they did not do a very good job of translating such principles into practice in the learning environments they created" (Alessi & Trollip, 2001, p. 37).

(c) The cognitive learning principles support the cognitive skills overlooked by the behaviorist, while the procedures taught in response to various stimuli are effectively supported by the behavioral principles. Reigeluth and Moore (1999) said, "Cognitive learning theory has contributed the most to understanding how best to teach and test this type of learning [higher order thinking skills]" (p. 55). The cognitive learning theory provides grounding for a wide range of instructional designs, which support all learning situations where the cognitive skills are taught. Learning theories provide a theoretical basis for the instructional designs and provide insight into what the instructional design needs to do to promote effective learning. The strengths and weaknesses of the learning theory underpinning the instructional design will affect the effectiveness of the learning an individual instructional design can achieve.

(d) Cognitive research has shown the learning of HOTS is not a change in observable behavior but the construction of meaning from experience (Johnson & Thomas, 1992; Thomas, 1992). Thomas (1992) also asserted that there are three types of cognitive theories upon which teaching strategies should be based. These three cognitive theories have gone unchallenged for twelve years; thus, his recommendation should be considered. These two cognitive theories and the constructivist theory are (a) information processing theory, (b) knowledge structure theories, and (c) social history theory (Thomas, 1992). The information processing theory explains how the mind takes in information (Information Processing Theory, 1996), knowledge structure theories depict how knowledge is represented and organized in the mind, and social history theory explains the vital role of the cultural context in the development of individual thinking. Information processing and knowledge structure theories refine and focus the cognitive learning theory, while the social history theory is considered a constructivist theory. The distinction between the cognitive and the constructivist learning theories may be arbitrary because the constructivist theory is also considered a cognitive theory. That is, they both involve the unobservable constructs of the mental processes of learning rather than observable behavior.

(e) The strength of the cognitive theory is its support of the presumed internal processes necessary in learning cognitive skills. Conversely, the weakness mentioned earlier concerning its failure to implement collaboration, communication, and transfer reflects that this theory does not fully support and explain teaching HOTS. The constructivist theory appears to overcome these weaknesses. Constructivist learning theory and its construction of knowledge will be discussed next.

(5) *Constructivist Learning Theory.*

(a) The constructivism approach asserts, "learning is a process of people actively constructing knowledge, where traditional instructional methods, such as memorizing, demonstrating, and imitating, are considered incompatible with the notion that learning is a process of construction" (Alessi & Trollip, 2001, p. 32). According to Reigiluth and Moore (1999), the following principles or suggestions are typically promoted as ways to accomplish the goal of allowing learners to construct their own knowledge:

> (a) Emphasize learning rather than teaching, (b) emphasize the actions and thinking of learners rather than of teachers, (c) emphasize active learning, (d) use discovery or guided discovery approaches, (e) encourage learner construction of information and projects, (f) have a foundation in situated cognition and its associated notion of anchored instruction, (g) use cooperative or collaborative learning activities, (h) use purposeful or authentic learning activities, (i) emphasize learner choice and negotiation of goals, strategies, and evaluation methods, (j) encourage personal autonomy on the part of learners, (k) support learner reflection, (l) support learner ownership of learning and activities, (m) encourage learners to accept and reflect on the complexity of the real world, and (n) use authentic tasks and activities that are personally relevant to learners. (Alessi & Trollip, 2001, p. 32)

(b) Constructivism also maintains that traditional methods [tutorial and drill instruction] produce knowledge that does not transfer well, that is, it is inert knowledge. Constructivist suggest that methodologies such as hypermedia, simulation, virtual reality, and open-ended learning environments are of more benefit to learners, allowing them to explore information freely, apply their own learning styles, and use software as a resource rather than as a teacher (Alessi & Trollip, 2001).

(c) A number of theories within the constructivist approach support various aspects of the constructivist theory. These theories include the social history theory, recommended by Thomas (1992) in promoting thinking skills, and the situated learning theory. According to Thomas (1992), the social history theory explains the development of individual thinking as it may apply to one’s social responsibility, it provides insight into the role of previous schema in long-term memory and the role of cultural context, and it provides an explanation for making a rational decision on what to believe. Because the social history theory does not explain what to do as well as the situated learning theory, the situated learning theory is better suited to teaching cognitive skills in aviation. That is, the situated learning theory recognizes the importance of the learning context and its effect on learning rather than on social development; hence, the situated learning theory should be more applicable to aviation. Lave’s situated learning theory recognizes (a) the role of previous schema, (b) the schema’s effect on learning new knowledge, and (c) how knowledge needs to be presented and learned in an authentic context without emphasizing the cultural aspects of the social history theory. It also emphasizes the learning settings, the effect of prior experience and knowledge, how learning requires social interaction, and collaboration (Lave, 1996). Thus, the situated learning theory is better suited to explaining and supporting the learning of HOTS.

(d) However, “growing research evidence indicates that constructivist methods work better only for learners with well-developed metacognitive skills. Some evidence also indicates that constructivist techniques are very time consuming. … Constructivist techniques are good for some types of learning, some situations, and some learners, but not all" (Alessi & Trollip, 2001, p. 39). Additionally, the points offered by Driscoll (2000) and Perkins (1991) are worthy of note; that is, "there is no single constructivist theory of instruction" (Driscoll, 2000, p. 375) and:

> Constructivist theory rests on the assumption that knowledge is constructed by learners as they attempt to make sense of their experiences. Learners, therefore, are not empty vessels waiting to be filled, but rather active organisms seeking meaning. Regardless of what is being learned, constructive processes operated and learners form, elaborate, and test candidate mental structures until a satisfactory one emerges (Perkins, 1991a) (p. 376).

> Driscoll helps clarify Alessi and Trollip's account of the constructivist theory. In other words, learning occurs when an individual makes sense out of information he or she has perceived from one or more of their senses. How information is perceived is limited or controlled by the individual's prior knowledge and experiences. The meaning constructed by the individual is further changed or modified by the individual's prior constructed meaning (knowledge) as the individual attempts to fit the new knowledge into the context of his or her prior knowledge. Conflicts between the new information and existing knowledge are resolved by modifying the new, the existing knowledge, or both. Modification of existing knowledge is not likely to occur unless other existing knowledge supported the need to revise the conflicting, existing knowledge. Otherwise, the new information may be rejected if the conflict cannot be rationally resolved. The implications in this theory are that it is unlikely the individual's constructed meaning is like any other person's knowledge unless (a) very similar learning had occurred throughout the lives of the two individuals and both individuals' sensory systems worked the same or (b) that both individuals had received extensive information on the specific subject. Ultimately, this theory illustrates the importance of prior knowledge. It illustrates the complexity and challenge of teaching and learning.

(e) Clark (1999) points out additional concerns about the constructivist approach. That is, while individual meaning construction facilitates thinking skills, there is little support for building a common set of knowledge and skills among learners in constructivist instructional designs: "the uniqueness of constructed knowledge is acknowledged" (p. 181). Naturally, these issues with the constructivist learning theory are problematic in teaching judgment skills in aviation. Clark's (1999) comments about the constructivist approach providing little support for building a common set of knowledge and skills is a particular concern in aviation where a gap in knowledge or skills would undermine safety. Furthermore, Driscoll (2000) said constructivist techniques are not good for all learning situations and all learners. Consequently, instruction in aviation that is based on the constructivist theory should only be used in combination with other approaches. These difficulties may not be a problem in situations where misjudgments are not critical or dangerous. In aviation the procedural task and the stimulus-response support of the behaviorism, the information processing theory of the cognitive theory, and the situated learning of the constructivist theory are all required to fully explain and support the development and transfer of HOTS.

C. Instructional Designs Supporting HOTS

1. To teach HOTS effectively using the methods and strategies described in the previous section an appropriate instructional design must be utilized. The challenge of teaching aeronautical knowledge to the application level of learning as well as the need to teach the underlying thinking skills effectively needed to improve aeronautical decision-making can be met by incorporating instructional designs that are based on problem-based learning (PBL). This review will compare and contrast three such instructional designs including the collaborative problem solving, anchored instruction, and Landamatics instructional design. These three designs are problem-based learning (PBL) methods. After a short description of the problems arising from the current teaching practices in aviation education, the study will compare and contrast the theoretical underpinnings and the practical applications of the problem-based learning designs to aviation education. Problem-based learning designs represent a choice of instructional methods that can be applied to teaching the aeronautical knowledge and decision-making components of aviation education.

2. In any discipline, teaching HOTS, including the cognitive process and cognitive skills, presents a significant challenge to the instructor. Teaching HOTS effectively involves customizing the examination and exploration of the mental activity to meet the individual learning needs of the learner. According to Kerba (1992), “learning is characterized as an active process in which the learner constructs knowledge as a result of interaction with the physical and social environment” (What Strategies Develop These Skills section, ¶ 1). Kerba’s suggestions on developing HOTS contain several key issues in teaching these skills including that the instructional design must be an active process, the instruction must facilitate the learner’s construction of knowledge, and the instruction must recognize that knowledge is constructed from the physical and social environments. Kerba also suggests, “Learning is moving from basic skills and pure facts to linking new information with prior knowledge; from relying on a single authority to recognizing multiple sources of knowledge; from novice-like to expert-like problem solving (Thomas, 1992)” (1992, What Strategies Develop These Skills section, ¶ 1). In this suggestion, Kerba has described a learning process similar to the process used in learning any cognitive knowledge, that is, simple to complex and concrete to abstract. He has also pointed out the need to use a problem-solving approach, and this approach is commonly suggested in the literature on teaching HOTS. Howe and Warren (1989) phrase their suggestions differently but make the same points: “there needs to be a shift in many classes, from a teacher-centered classroom to a student-centered classroom in which students can be involved in collecting and analyzing information, paired problem solving, cooperative learning settings, simulations, debates, and critical reporting sessions” (What Does Research Indicate Regarding Teaching Critical Thinking section, ¶ 6).

3. Collaborative Problem-Solving Design

A brief description of the collaborative problem-solving design, anchored instruction design, and Landamatics instructional-design follows. As the name implies the collaborative problem-solving design combines the collaborative and problem-solving approaches into a single instructional design. The collaborative learning portion of this design provides guidance on organizing learning groups and suggests specific activities to structure their learning experiences. The problem-solving portion emphasizes the development of carefully constructed problems, tasks, or scenarios. These problems, tasks, and scenarios are provided to collaborative groups to solve the problems. Assistance is provided from the instructor and faculty tutors when needed. Learning to solve the problem or task without assistance is part of the learning process. Nelson's design combined the strengths of both methods (collaborative and problem-based learning) to provide a more comprehensive approach through the actual collaborative problem-solving process (Nelson, 1999).

4. Anchored Instruction Design

Bransford (n.d.) is credited with evolving the second PBL design, anchored instruction, from earlier work by Lave in situated learning. According to Bransford's theory, anchored instruction is situated in a context of an information-rich environment such as a videodisc. From this context (the videodisc, film, or other video material), students and teachers are encouraged to pose and solve complex, realistic problems (CTGV, 1993). The main purpose of anchored instruction is to overcome the inert knowledge problem prevalent in other instructional methods when the information is presented in a classroom, and it is not presented in the context within which it will be used. For instance, aircraft systems are typically taught in a classroom, but this information must be recalled in-flight when an equipment malfunction occurs. Classroom knowledge commonly cannot be recalled in-flight since the environment or situation is different from that which the information was learned. The article *The Anchored Instruction Theory* (n.d.) describes it best:

> Anchored instruction focuses on creating anchors with embedded data design that generates students' interest and encourage students to identify, define, and solve real-world problems by themselves. When instruction is situated around an anchor, the complex problem space is referred to as macrocontext.

That is to say, the anchor provides the link between the learning and the application of the knowledge in environments where it is needed, thus the information can be recalled and applied in-flight.

5. Landamatics Instructional Design

(1) The third design is the Landamatics instructional design theory. According to Landa (1999), it is a methodology for teaching general methods of thinking. Landa identifies general logical structures of various subject matters and determines methods of handling those structures. Landa offered three strategies (or methods) in his theory including guided discovery, expository teaching, and combination method. These three strategies are then used to learn any subject matter through identifying the general logical structures of the subject. Landa suggests these strategies are to be practiced until they are first internalized and then automated.

(2) Internalization and automation are typically described as expressing a process or procedure in the learner's own words so that the learner fully understands the actions

> needed in each step of the process or procedure. In turn, automation is practicing or drilling a procedure until it can be accomplished without thinking about the steps in the procedures. This is also described as being able to accomplish the steps directly from long-term memory without having to recall the steps first in conscious or short-term memory. An example of automation is being able to steer an automobile along a road without having to steer consciously. It is necessary to automate such skills if a person is to be able to watch for other drivers, look for a turnoff, and do the many other things a driver must do while driving. Similarly, a pilot must automate basic aircraft control in order to free conscious memory (STM) for handling abnormal or emergency situations. There are many other examples related to flying where a pilot must automate basic skills or tasks to free up working memory for other mental requirements. Automation is important to aviation education because sufficient working memory must be available (free) for the pilot to be able to solve problems when problems occur in-flight.
>
> (3) The collaborative problem solving, anchored instruction, and Landamatics instructional design theories are the three examples of PBL instructional designs that will be compared for applicability to aviation education. The three instructional designs selected for this comparison represent possible alternatives or supplemental approaches to the current teaching practices used in pilot training and aviation education, which will meet the instructional requirements of aeronautical knowledge and decision-making components of aviation.

D. Unanswered Questions

1. This section addresses unanswered questions and identifies areas where additional research is needed. The literature showed PBL to be the answer to meeting the instructional challenges in aviation education; however, PBL designs have not been tested and proven effective in aviation education as they have in other disciplines. The strength of PBL appears to lie in helping the learner gain a deeper understanding of the information and in the learner improving his or her ability to recall the information. This appears to result when the material is presented as an authentic problem in a situated environment that allows the learner to “make meaning” of the information based on his or her past experience and personal interpretation. Hannafin, Land, and Oliver (1999) describe it best:

> Direct instruction typically employs clearly articulated external learning objectives. These tend to isolate critical information and concepts, organize to-be-learned concepts into carefully ordered sequences to reflect the presumed hierarchical nature of knowledge, and employ strategies that induce differential allocation of attention and cognitive resources. They feature a great deal of external engineering of both to-be-learned knowledge and skill as well as the strategies presumed to promote learning (Hannafin, 1995).
>
> [Experience-based problem-solving designs] are less amenable to convergent learning tasks, where different learners need to develop the same knowledge, procedural skills, or interpretation. Since they encourage personal inquiry, it is unlikely that all individuals will encounter information sources, much less interpret them consistently. [Thus, they]

tend to be less effective for learning of a strict, accountability-based nature or when efficiency in terms of acquisition time is critical. (pp. 119-120)

2. The information cited here refers to the open learning environments design; however, it is equally true of any constructivist based PBL. In aviation, the biggest challenge to PBL designs will likely come from the practitioner's reluctance to accept that learners are not being required to develop the same knowledge and procedural skills, and they are not required to interpret the information in the same way, rather than from the instructor's ability to implement effective design. PBL represents a significant departure from the competency-based or maneuver-based approaches currently being used in aviation education.

3. *Current Practices.*

(1) Before an in-depth comparison of online vs. face-to-face instruction can be done, it is important to consider the specific instructional needs of aviation education. This discussion will begin with a review of current practices and include the nature of pilot training, limitations of the lecture method, student participation, and the challenges presented by aeronautical decision-making.

(2) Current practices in aviation education stem from the FAA guidance on how pilot training will be conducted in the (AIH) (1999) and from various Federal Aviation Regulations (FAR) establishing the training requirements for the certificates and ratings of pilots, flight instructors, and flight schools. The instructional challenges include providing effective instruction in aeronautical knowledge at the appropriate level and aeronautical decision-making skills in large classes and providing effective and efficient customized instruction that accommodate individual learner's needs. Understandably, these are common challenges facing other disciplines attempting to teach any cognitive skill or specifically the cognitive skills used in judgment and decision-making.

(3) Additionally, aircraft automation, advanced instrumentation, ADM, and ADM related topics are not taught in the traditional transition training. ADM and ADM related topics include the poor-judgment chain, crew resource management (CRM), decision-making process, risk management, factors affecting decision-making, stress management, use of resources (internal and external to the aircraft), workload management, and situational awareness. The information is available to every pilot through the various document and advisory circulars published by the FAA; however, it is not commonly covered by the instructor in transition training, that is, checkout in a new aircraft during factory training.

4. *The Nature of Pilot Training* .

The examination of the instructional challenges found in aviation will continue with a discussion of the nature of pilot training. Pilot training is multifaceted; it consists of aeronautical knowledge, skills performance, and aeronautical decision-making (ADM) components (14 CFR Part 61 and Part 141). Each component has its own instructional requirements including procedural knowledge, psychomotor skills, and cognitive skills respectively. The FAA describes four methods of instruction to facilitate learning of these components including lecture, demonstration-performance, cooperative or group learning, and guided discussion (AIH, 1999). The guidance provided by the FAA is quite adequate for teaching the three components in the pilot training setting; however, it is problematic in the aviation education setting. This is caused, in part, by the difference in class size and the corresponding loss of individualized attention occurring as the class size increases. Typically, pilot training is conducted one-on-one or in a small group, while the aviation education classes are much larger.

5. *Limitation of the Lecture Method.*

(1) The lecture method is well suited to teaching the aeronautical knowledge component in the aviation education setting because it is efficient. In small groups, it may be more desirable to use the guided discovery because it is more effective and efficiency is not an issue. The lecture works well when (a) there is a substantial amount of information that needs to be delivered to large numbers of students, (b) a framework or overview is needed, (c) there are many sources that need to be summarized and synthesized, and (d) the personal experiences of the instructors provide enthusiasm (*The Lecture Method*, n.d., Advantages/ Disadvantages ¶ 1). Typically, all disciplines in higher education depend on the lecture method as the cornerstone for communicating theories, ideas, and facts to students (*The Lecture Method*, n.d.).

(2) *Student Participation.*

(a) The FAA suggests student participation should be encouraged through questioning in the informal lecture method (AIH, 1999), while higher education emphasizes providing frequent opportunities for rehearsals and learner interaction (Clark, 1999; Chickering & Gamson, 1987). The FAA and higher education also suggests the cooperative or group-learning method is an instructional strategy with promising possibilities for academic achievement (AIH, 1999; Clark, 1999). The FAA said the guided discussion could be used:

> During classroom periods, and preflight and post-flight briefings after the students have gained some knowledge and experience. Fundamentally, the guided discussion method is almost the opposite of the lecture method. The instructor's goal is to draw out what the students know, rather than to spend the class period telling them. (AIH, 1999, p. 5.7)

This description of the guided discussion method is typical of the brief and limited guidance provided by the FAA on teaching methods.

(b) In pilot training settings, a heavy emphasis is placed on reading assignments and self-study as the methods for students to obtain aeronautical knowledge (AIH, 1999). These methods are not the most effective and efficient methods of learning for all learners (Reigeluth, 1999). Again, in pilot training settings, the training is self-paced and efficiency is not a concern. Effectiveness is a concern and is an instructional challenge for aviation education.

(c) The primary challenge in aviation education and pilot training is teaching aeronautical knowledge to the application level of learning and aeronautical decision-making skills so it may be applied to the in-flight operation of the aircraft. The FAA specifically requires the pilot to demonstrate his or her mastery of the aircraft, to operate the aircraft safely with precise aircraft control, and demonstrate sound judgment and ADM (*Instrument Rating Practical Test Standards*, 2004). This relationship between teaching the concepts and theories of flight in the classroom or during the “ground instruction” and then applying them in flight is the essence of the pilot training challenge. Close ties between the classroom instruction and the flight training are usually not maintainable in aviation education programs. Typically, the classroom instructor is not the same flight instructor, and the classroom instruction is not synchronized with the flight training.

(d) The lack of instructor continuity creates a problem for the aviation education programs that is normally not a problem in a pilot training program. This problem is an inability of the student pilot to apply the knowledge learned in the classroom to the in-flight environment. This could be described as inert learning. For example, the student pilot is taught basic aerodynamics in the classroom. When classroom and flight training is synchronized, the concept and theories taught in the classroom are demonstrated in-flight. This allows the student pilot to see these concepts and theories, thus gain a deeper understanding of these concepts and theories. Furthermore, the understanding of these concepts and theories helps the student pilot understand what must be done with the aircraft controls to make the aircraft do what the pilot wants the aircraft to do. When the classroom instruction and flight training is not synchronized, the deeper understanding is not gained by the student, and the student will not understand why control inputs are needed to get the aircraft to do what the pilot wants the aircraft to do. A pilot can be taught to fly without an understanding of basic aerodynamics; however, the pilot will typically be unable to anticipate the need for control inputs until the association between basic aerodynamics and aircraft performance is made.

6. *Challenge of Teaching Aeronautical Decision-Making.*

(1) The aeronautical decision-making and underlying thinking skills discussed earlier require more learner-centered instruction to achieve the desired learning outcomes than is typically provided in the lecture method. The lecture method needs to be supplemented with other instruction involving some form of problem solving, scenario-based, or case study instruction in order to accommodate learner differences adequately and individual learner needs for this component of the program. The guided discussion method suggested by the FAA may be used effectively to teach aeronautical decision-making, if higher order thinking skills strategies are employed. Instructors should be careful not to block critical thinking by offering the “school solutions” or suggesting that there is only one correct answer. Not blocking critical thinking is an instructional challenge facing both aviation settings.

(2) This examination of the current practices in aviation has identified several instructional challenges and limitations that are typical of face-to-face instruction. These challenges and limitations include how the instruction can be provided effectively in large classes, how to ensure learning is accomplished to the application and correlation

levels of learning (AIH, 1999, p. 9.1), and how the instruction can be customized to accommodate individual learner's needs.

E. Summary of the Literature

1. Enhancing the Development and Transfer of HOTS

(1) The cognitive skills (analysis, synthesis, and evaluation) needed to make good judgments and decisions can be taught. The aviation community needs to incorporate the instruction of these skills into its aeronautical decision making training to reduce the number of human factors related accidents. Cognitive skills are being taught outside of aviation as HOTS and they are taught by integrating thinking skills strategies in combination with other learning activities. In other words, to enhance the learner's ability to make good judgments and decisions, the learner must improve his or her HOTS. These skills can be taught effectively and efficiently with instructional designs, which include redirection, probing, reinforcement, asking higher order questions, lengthening wait-time, amongst other things.

(2) The requirements for teaching HOTS are instructional approaches designed to promote the development of thinking skills including strategies using specific mental operations, engaging learners in some form of mental activity, examining that mental activity, challenging the learner to explore other ways to accomplish the task or solve the problem, and then having the learner determine which way is best. HOTS also requires (a) customizing the examination and exploration of mental activity to meet the individual learning needs in an active process, (b) constructing knowledge as a result of interaction with the physical and social environment in student-centered environments, and (c) engaging students in collecting and analyzing information, paired problem solving, cooperative learning settings, simulations, debates, and critical reporting sessions. These strategies could be guided discovery, expository teaching, or a combination strategy presented in a PBL design.

(3) The transference of knowledge from the learning environment to its practical application is not a separate problem from the learning and application of HOTS. It is the problem addressed in the literature for teaching HOTS. That is, learning the cognitive skills underlying the decision-making process in a learning environment so that they may be recalled from LTM and applied when an ill-defined, ill-structured, complex problem-solving situation occurs is the instructional challenge besetting the development of HOTS. Near-transfer teaching methods involving practicing or drilling systematic procedures may be used because there is little variance in the application of the procedure. For example, in an aircraft abnormal or emergency situation, where no real thought is required to handle the situation and a simple "maintain aircraft control, identify, verify, and then complete the appropriate checklist" will do.

(4) In contrast, far-transfer teaching methods may be needed in other abnormal or emergency situations, particularly with ill-structured, ill-defined, and complex problems where the pilot must use extensive judgment, must use a different approach, or where there are no set steps or set procedure in deciding what to do. Developing authentic and

realistic problems with very similar circumstances to those occurring in-flight will promote near-transfer. On the other hand, when problems have somewhat different circumstances, judgment, or unique problem solving is required, then training methods are needed to promote far-transference. The training methods to promote far-transference include beginning with near-transference type problems, progressing toward more abstract and complex problems, and finally, continuously relating each problem to the environment where these ill-defined, ill-structured, and complex problems will be encountered.

(5) The learning theories supporting and explaining the development and transfer of HOTS include behavioral, cognitive, and constructivist learning theories. These theories also include refined or focused theories such as the information processing, knowledge structure, and situated learning theories.

(6) Information processing and knowledge structure theories are cognitive learning theories, while situated learning theory is a constructivist theory. Collectively, they support the learning activities discussed earlier and provide the theoretical underpinnings for teaching and learning thinking strategies. They support and explain the guided discovery, expository, problem-based learning, simulation, tutorials, team building, redirection, probing, reinforcement, and higher order question approaches to learning. These learning models provide a choice of theoretical foundations upon which instructional designs for different learning settings can be based. They also provide a range of learning models the instructor may chose from to customize the instruction to the individual learner’s needs within the cognitive theories.

(7) HOTS are most effectively learned through a blend of learning theories. The behavioral learning theory supports learning the mental process and the procedural processes employed in normal and in the typical abnormal and emergencies situations. However, the behavioral learning theory provides little support to how atypical problems are solved (problems where the learner does not have previous experience or training) and to how ill-defined, ill-structured, complex problem solving is learned.

(8) These problems are better explained with learning theories that support cognitive learning, namely cognitive and constructivist theories. In some situations the learning process is driven by information-processing which emphasizes perception and attention, encoding of information, memory, comprehension, active learning, motivation, locus of control, mental models, metacognition, transfer of learning, and individual differences. Moreover, in other situations, the process will be driven by individual construction of meaning, situated learning, and collaborative learning.

(9) The strategies for teaching HOTS employ the same learning theories used in acquiring other mental skills. Cognitive skills should be taught for simple to complex and from concrete to abstract. The learning theories supporting learning cognitive skills are not either cognitive or constructivist; rather they are both. Mixing instructional designs that are based on different learning theories should allow the educator to take advantage of the strengths of each learning theory and enhance the development and transfer of the cognitive skills beyond any one theory. Enhancing the development and transfer of

HOTS is influenced by the ability of the learning theories to accommodate these requirements, that is, promote the development and transfer of thinking skills necessary to solve problems not experienced or practiced previously and to solve ill-defined, ill-structured, complex problems.

2. *Instructional Designs*

(1) The literature reviewed for this study has suggested the critical need to improve aeronautical decision-making training could be met with collaborative problem solving, anchored instruction, and Landamatics designs. The learner-centered environment needed to facilitate individual learning of ADM calls for the consideration of instructional methods beyond the lecture method typically employed in aviation instruction in higher education classrooms.

(2) The PBL environment employed in each of the three selected designs addressed the individual learning needs presented by aeronautical knowledge and aeronautical decision-making of aviation education. This study has examined anchored instruction, collaborative problem solving, and Landamatics instructional designs as potential alternatives or supplemental approaches, which could be used to improve the quality of instruction currently used in aviation education.

(3) The three theoretical approaches to design represent the new paradigm of instruction, which includes higher levels of learning, greater customization of the learning experience, and much greater utilization of information technology, fellow learners, and other resources for learning. These are the things needed in aviation education to improve pilot thinking skills. They reflect a common problem-based learning environment; thus, they exhibit many similarities in their type, control, and focus of learning. While they show differences in their grouping, interactions, and support of learning, they primarily demonstrate the strengths and weaknesses of PBL.

(4) Collectively, collaborative problem solving, anchored instruction, and Landamatics instructional design theories represent a comprehensive system of instructional designs that could be applied to the educational challenges presented by the requirements to teach aeronautical knowledge and decision-making in aviation education. These designs provide a variety of instructional methods that motivate student learning and provide the teacher ample choice of instructional tools to meet specific aviation teaching requirements effectively and efficiently.

CHAPTER 3: METHODOLOGY

A. This study used an experimental research design to determine if problem-based learning (PBL) significantly enhance the development and transfer of higher order thinking skills (HOTS) in aviation education. The experiment compared the effects of three methods of instruction and determined their effects on upper-division college students' aeronautical decision-making (ADM) skills and the quality of their subsequent pilot judgments. The study addressed the following two research questions:

> 1. What is the effect of the method of instruction on upper-division college students' development and transfer of HOTS?
>
> 2. Does problem-based instruction increase the quality of pilot judgments, automation management, situational awareness, and performance compared to instruction that is not problem based?

The experiment examined the research hypothesis that PBL will significantly enhance HOTS and subsequently improve the quality of pilot judgments and decision-making.

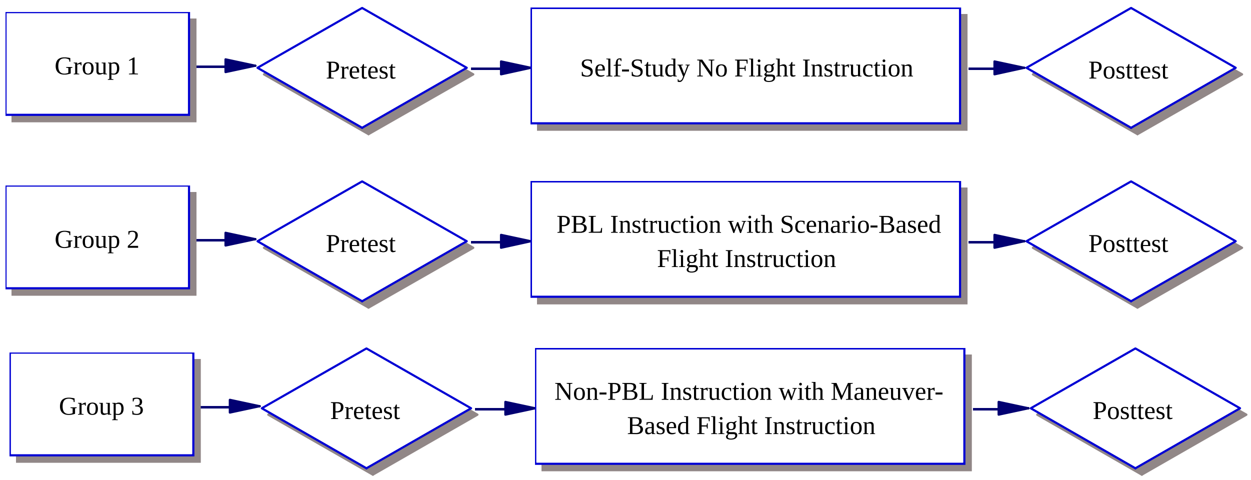
B. Research Design

1. This study used the pretest-posttest control-group experimental research design to determine the effect the problem-based learning method of instruction has on the development and transfer of HOTS and subsequent pilot judgments, as compared to the effects self-study and traditional methods of instruction have on HOTS and pilot judgments. Initially 48 students from several Gas Turbine Engine (Avit 327) classes offered in a collegiate aviation program were randomly assigned to three groups (n=16 per group). As the experiment progress, 17 new participants from three Certified Flight Instructor (Avit 414) classes were randomly assigned to refill the three groups to 15. This process is discussed in more detail later in this section. The high drop out rate resulted in many occurrences of missing data. Participants with missing data were eliminated from the final analysis. This resulted in N=33 and n=10, n=12, and n=11 (groups 1 through 3, respectively). The three groups were (a) control group (self-study) received no ground or flight instruction, (b) a treatment group (problem-based) receiving PBL instruction with scenario-based flight instruction, and (c) an alternate treatment group (maneuver-based) receiving traditional instruction or non-PBL instruction.

2. The pretest-posttest control-group design (see figure 1) provides the best comparison of the method of instruction when realistic constraints are employed between the treatment group and the current practice used in aviation education. This study was conducted with upper-division college students holding commercial single- and multi-engine certificate and instrument rating (CMIR) to validate the test instrument and to make an initial determination of the effectiveness of the methods of instruction in improving pilot decision-making skills and subsequent judgment. All participants were instrument current at the beginning of the flight training portion of the experiment. The experiment used college students because they were available for experimentation and because testing new buyers receiving factory training would interfere with the training provided by the aircraft manufacturer. A discussion of possible future studies at factory training sites is provided in chapter 5. This study has established a baseline for follow-on

studies and future on-site studies (at factory training sites) for testing the effectiveness of HOTS training.

Experimental Research Design



Group 1: Control Group (Self-Study)
Group 2: Treatment Group (Problem-Based)
Group 3: Alternate Treatment Group (Maneuver-Based)

Figure 1: The Pretest/Posttest Control Group Experimental Research Design

3. The upper-division college students were volunteers who had completed course work and flight training in a collegiate aviation program toward becoming a commercial pilot. The study does not assume that these college students accurately represent the general pilot population in the United States. It is assumed that students do not possess similar flight experience, flight time, and years of flight experience as the pilots currently buying TAA. To determine the characteristics of these participants, demographic data was collected including sex, age, pilot certificates and ratings, years certificates and ratings have been held, recurrent training experience, types of aircraft flown, and several categories of flight hours. Marketing research by the aircraft manufacturer reflect that the typical TAA buyer is middle age or older and has a wide range of pilot licenses, certificates, types of aircraft flown, and flight hours. Other differences are anticipated to exist as well; however, none of these differences should affect the study or the results. For example, marketing data indicate that most buyers are successful business people rather than at the beginning of their working lives as the students are. Thus, it is assumed that typical buyers will have significantly more experience making decisions as well as more insight on the quality of their decision making. These assumptions are general in nature because they are made without full access to the marketing research and remain general in nature until demographic data can be collected during follow-on studies at the factory training facilities.

4. The instructional method used in this study is a specific manufacture’s application of a FITS transition syllabus for TAA. “Transition training” means the training the pilots need to safely fly

the Cirrus Design model SR22 aircraft where the pilot has been a qualified pilot flying at least one other single-engine piston aircraft. The syllabus is an example of the type of factory training the FITS research team is recommending manufacturers use for TAA, and at the time this study was started, it was the only fully implemented training of its type. In this study, factory training refers to the training provided by the aircraft manufacturer or by a factory approved training provider upon the delivery of a new aircraft to a buyer. Typically, it is the training included in the purchase price of a new aircraft regardless of who provides the actual training.

5. The transition syllabus and instruction for the problem-based (treatment) and maneuver-based (alternate treatment) were developed by the University of North Dakota Aerospace Foundation (UNDF) under contract to provide Cirrus Design factory training. Furthermore, the problem-based method of instruction was developed under a partnership between the FITS research team and UNDF. UND Aerospace received the training contract in October of 2002, after several fatal Cirrus aircraft accidents and several other incidents and accidents. January 2003, UND Aerospace began working with the FITS research team to develop the FITS transition-training model. The Cirrus flight-training program provided the developmental model of the original FITS generic transition syllabus. The FITS generic transition syllabus has served as the model for several subsequent factory-training syllabi.

6. The instruction for the self-study, treatment, and alternative treatment began with self-study of the Cirrus Design SR22 Pilot’s Operating Handbook (POH) with accompanying CD-ROM based training materials. In the case of the treatment instruction, scenarios were presented and the pilot was asked to research the POH to complete the training successfully. Open-ended questions were asked to relate the material to the pilot’s previous experience and to develop a better understanding of the material as it relates to flying the new aircraft. In the case of the self-study and the alternative instruction, questions requiring fill-in-the-blank and short answers were asked. This instruction was designed to have the pilot find and learn factual information about the new aircraft. The CD-ROM continued Microsoft PowerPoint presentations using the same instructional methods; that was, the aircraft systems material is related to flying the aircraft in the case of the treatment instruction and limited to factual information in the self-study and the alternative treatment instruction.

7. Flight instructors continued the transition training by providing a review of the aircraft systems through ground briefing and five flight lessons in the ATD for the treatment and alternative treatment groups. The treatment group received PBL in both the ground briefing and flight lessons, while the alternate treatment group received oral quizzing of factual information and maneuver-based flight training. Aeronautical decision-making and single pilot resource management (SRM) including resource, risk, automation, and information management were emphasized in the treatment instruction. These items were virtually ignored in the alternate instruction just as they typically would be in traditional transition training. Normally, factory training for non-TAA often varies from no training to several hours of training for the current and appropriately rated pilots. When pilot proficiency is lacking due to loss of currency or when pilots require additional certificates or ratings, additional training can be obtained at an additional cost. Often, the factory training only consists of a demonstration flight to several hours of maneuver-based flight instruction (B. Smith, personal communication, November 8, 2004). The treatment group received a version of the FITS recommended training methods, PBL instruction with scenario-based flight instruction. The alternate treatment group received

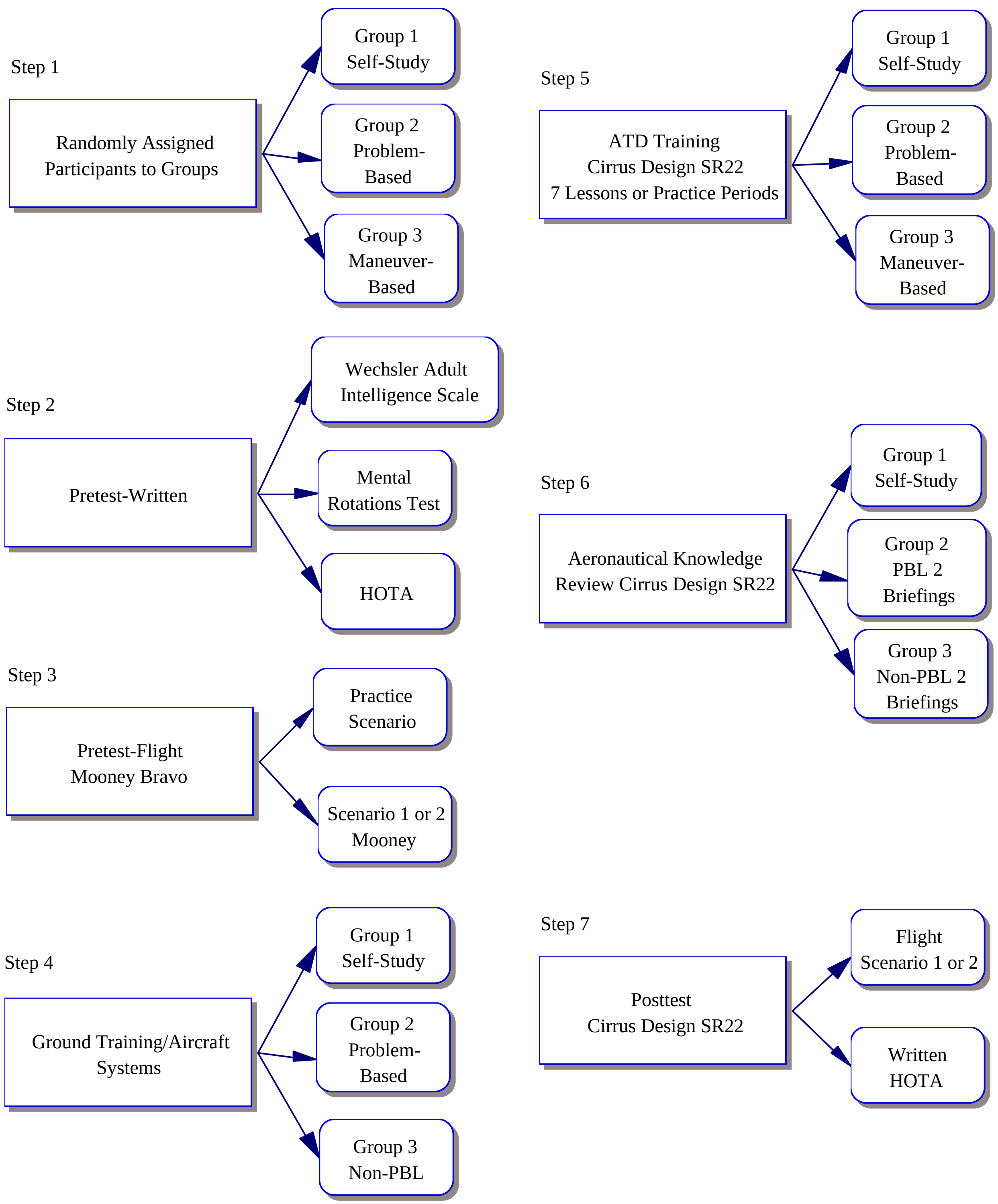
traditional non-PBL instruction and maneuvers-based flight training. The self-study group received no instruction and was provided equal time on the advanced training device.

8. Other constraints imposed on the experiment were the availability of the training equipment and participants. A prototype of an ATD, personal computer-based flight simulator, was purchased for the FITS research project. It was used for this study, and it was the only TAA ATD available at the time. Each participant was required to complete approximately 10 hours of training and testing on the ATD. This imposed a practical limit of 10 participants per group to meet the original terms of the grant. Thirty participants required approximately 600 hours of flight training on the ATD, and it was difficult to complete the study with the targeted students because the current semester ends in May and the students will only be readily available through the end of April. Additional participants were not available until the beginning of the next term. Under the original terms of the grant, the FITS project was required to have the initial study completed by the end of May 2005; however, an extension was granted and additional participants were added during the subsequent term.

9. In this study the experimental treatment, independent variable, was the method of instruction—used PBL, the comparison group received the alternative treatment—non-PBL, and the control group received no instruction, self-study. The treatment and alternative treatment groups received instructor led and CD-based instructions. The alternative treatment did not use PBL instructional designs. The alternative treatment involved only instructional methods typically recommended by the FAA for teaching aeronautical knowledge, aeronautical decision-making, and maneuvers-based flight training. The control group received a demonstration flight similar to a typical non-TAA to show how everything works type flight. The dependent variable was the academic achievement in HOTS and the subsequent quality of pilot judgment.

10. According to Gall, Borg, and Gall (1996), the pretest-posttest control-group design does not suffer from potential internal validity problems and only suffers from one source of potential external validity, that is, from a possible interaction between pre-testing and experimental treatments. The pretest-posttest control-group design provided the strongest indication that a specific factor caused the effect observed and not some other factor, given the constraints of this experiment. The constraints of the experiment may, however, introduce other external validity issues not addressed by Gall, Borg, and Gall (1996) that should be considered. One such issue is the small sample used in the experiment due to the time constraints and limited availability of both the participants and the ATD. Three groups of 16 participants each yields 48 participants. Forty-eight participants represent less than 2% of the current pilot population owning TAA. This was an estimated number based on Cirrus' recent announcement that it delivered its 1,000th aircraft and on Diamond Aircraft recently awarded aircraft certification. The sample size may be adequate for the current pilot population owning TAA; however, the number of owners is expected to increase rapidly as other manufacturers obtain their TAA certifications and as Cirrus increases its weekly deliveries to between 8 and 10 aircraft per week. The group size will be more at risk for distortion resulting from individual performance differences such as learning rate or a participant not feeling well during the posttest evaluation. Hence, it was necessary to pay close attention to distractions and outliers.

Research Flow



Note: All groups received the same pretest and posttest. Half of the participants from each group will receive Scenario 1 for the pretest and Scenario 2 for the posttest. The other half will receive Scenario 2 for the pretest and Scenario 1 for the posttest.

Note: Scenario 1 and 2 are prescribed flight patterns with specific in-flight events programmed into a scripted flight profile.

Figure 2: Research Flow Chart

C. Research Protocol

1. Figure 2 outlines the research flow that was used in this study. The first step in conducting the experiment was to assign the students randomly to the three groups. As the experiment progress, participants dropped out, and the school term changed, 17 new participants were added. The new participants were also randomly assigned to the three groups. Every participant had an equal chance of being assigned to a particular group.

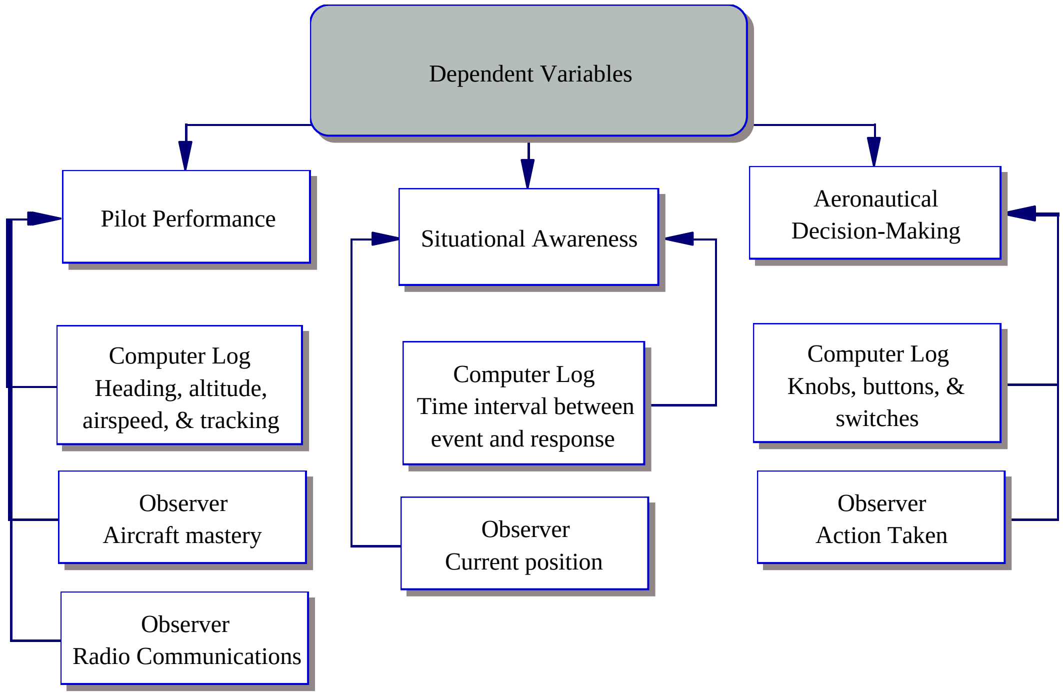
2. All participants received a pretest and a posttest. The pre- and posttests were a 45-minute pilot performance assessment in an ATD (see Appendixes A and B). The pre- and posttests were balanced to ensure that the difference in the scores between the pre- and posttests were valid reflections of pilot performance, situational awareness, and aeronautical decision-making and not a difference in the difficulty of the tests. That is, half of the participants from each group received Scenario 1 for the pretest and Scenario 2 for the posttest. The other half will receive Scenario 2 for the pretest and Scenario 1 for the posttest.

3. The 45-minute pilot performance assessments used two similar prescribed flight patterns, titled Scenario 1 and 2, which were adapted from a set of patterns developed to measure pilot performance in an earlier study by Petros et al. (2003) on the effects of alcohol on pilot performance. The Petros et al. (2003) study found the patterns to be both valid and reliable in measuring pilot performance and in measuring the changes in the pilot’s performance due to an external effect, alcohol. These patterns were modified from those used in the alcohol study to follow a flight path that could be flown between actual navigational aids in the Minneapolis, MN area. The prescribed flight patterns have pre-planned events occurring at specific times. The prescribed flight patterns allow identical pattern 1 or 2 to be administered to each participant for standardized evaluation of the respective tests (see Appendixes A and B).

D. Data Collection

1. The data collected on the pilot performance assessment was captured by the computer in the ATD and by researcher observations. The ATD is a computer-based flight simulator, which provides a data capture function and provides emulation of many aircraft. Figure 3 illustrates how the data will be obtained in the study. The Mooney Bravo simulation was used for the pretest and the Cirrus SR22 aircraft was used for training and the posttest. The Mooney Bravo is a non-TAA that the participants are familiar with and have flown before and the Cirrus SR22 is an example of a TAA. The data capture capability includes the heading, airspeed, and altitude. The computer data capture rate was selectable; however, 1-second time intervals were used. The aircraft tracking error indicates the deviation from the desired position. These data points along with the researcher’s observation can be compared to the prescribed flight path to evaluate the pilot’s performance. For example, maintaining the desired heading, altitude, and airspeed within established parameters is required and the typical pilot should be able to accomplish this.

Variables for Data Collection



Note: The dependent variables that will be examined are listed in the second row while the sources of the data influencing each of the three categories of dependent variables are listed in the column under the respective dependent variable.

Figure 3: How the Data Was Defined and Obtained

2. The parameters, an acceptable range of variation, were established to allow the pilot to attend to other flight duties that often takes the pilot's attention away from maintaining precise aircraft control. The parameters tighten; acceptable range of variation is reduced, as the pilot moves toward the higher qualifications required for advanced certificates and ratings. That is, the pilot is held to a higher standard. Thus, the pilot's performance can be judged by how well the pilot holds these standards or how exacting he or she controls the aircraft.

3. The term deviation is used in this study to describe the difference between the actual heading, altitude, and airspeed and the desired heading, altitude, and airspeed. The parameters are in different units of measurement; hence, they were tracked as separate variables. Furthermore, the magnitude of a deviation on one parameter cannot be directly related to the magnitude of a deviation in either of the other parameters. Deviation score is defined in this study to be the number of units the pilot has deviated from the desired flight path. Deviations from the desired flight path indicate the pilot's ability or lack of ability to maintain aircraft control.

4. Other indications of pilot performance are (a) the percentage of correct radio calls against the number of radio calls, (b) the percentage of correct actions taken by the pilot opposed to the number actions directed, and (c) the percentage of radio calls correctly remembered. A

researcher will record a description of the action to supplement the computer recorded deviation data. The data recorded by the computer includes the deviation data, an over-head view of the ground track the aircraft flew, and a cockpit view visual references what the pilot saw during the simulator flight. The researchers' observation will be discussed later.

5. Situational awareness was measured by periodically pausing the simulator and asking the participant "what is your altitude," "what is your airspeed," "what is your heading," "where are you now," and "where will you be in 10 minutes?" This method provided a direct measurement of situational awareness; however, it is more disruptive and intrusive than passive researcher observation; thus, both methods were used.

6. Aeronautical decision-making was measured by assessing the appropriateness of the actions taken and the quality of aeronautical decisions from the pilot performance data, the researcher's observation of the pilot performance, and a written test of higher order thinking awareness. The higher order thinking awareness test was developed by the FAA Industry Training Standards (FITS) research team from Schraw and Dennison's (1994) Assessing Metacognitive Awareness survey. The three measurements were used so that a comparative analysis of pilot performance and aeronautical decision-making can be made.

7. Again, the data collected included (a) heading, (b) airspeed, (c) altitude, (d) written assessments, and (e) in-flight situations involving events and radio calls as indicators of pilot performance, situational awareness, and aeronautical decision-making. The amount of deviation from the desired position is important because it indicates the pilot's ability to maintain precise control of the aircraft. Precise control of the aircraft was judged against the criteria established by the FAA in the Instrument Rating Practical Test Standards (PTS) (2004). For example, the PTS specifies that the aircraft heading must be maintained within ten degrees of the appropriated heading. The PTS standard allows momentary deviations that do not cause the safety of the aircraft to be in question. The participants selected have previously demonstrated their ability to operate an aircraft within these standards. This was done during the pilot's initial instrument rating and periodically there after through instrument proficiency checks. All participants were current instrument rated pilots.

8. Additionally, the magnitude of the deviations was used as a measure of the pilot workload; that is, the greater the pilot workload the less attention the pilot has to devote to maintaining precise aircraft control. Pilots are trained to manage their workloads, thus failing to manage the workload effectively is an indication of bad pilot judgment. Likewise, the time interval between the first indication of a change and the pilot's response to that change is an indication of the pilot's situational awareness, while the specific action taken by the pilot is an indication of pilot judgment.

9. The final item in the pilot performance assessment is the researcher's observation of the pilot's in-flight decision-making score. Pilot performance was evaluated by a research assistant holding a certified flight instructor (CFI) certificate or specifically trained to conduct the evaluation. All research assistants were trained to provide the respective ground and flight training, and they were trained to evaluate the pilot's aeronautical decision-making skills. The research assistants did not evaluate his or her assigned students. The CFIs, research assistants, observed the pilots' performance while the ATD records the heading, altitude, and airspeed.

These observations were the pilot's choice of the best course of action in response to an in-flight situation including events and radio calls mentioned earlier.

E. Pilot performance outside the prescribed standards was noted as deviation and performance errors within the prescribed standards was tracked and recorded by the data collection function of the ATD. Major deviations indicate decisional errors; thus, the heading, altitude, and airspeed were not useful. Deviation from the prescribed heading, altitude, and airspeed indicate cognitive loading and task saturation for the pilot. The heading, altitude, and airspeed errors were used as indicators of the pilot's performance along with the researcher's observations to evaluate the appropriateness of the participant's use of the available automation and the participant's decision-making skills. The pilot's ability to select the appropriate actions in response to the introduction of an event, such as a system malfunction, indicates the quality of that person's aeronautical decision-making. Major deviations, lengthy time intervals between introduction of an event and the pilot's response to the event, and specific actions taken by the pilot were analyzed as separate data points to provide a complete picture of the participant's performance.

F. Instructors and Instruction

1. Six certified flight instructors (CFIs) and two research assistants were used to train and to evaluate the pilot's performance during the pre- and posttest flight-performance assessment. A blind evaluation approach was used; that is, the CFI providing the training was not used to evaluate his or her own students. Participants were randomly assigned to the evaluators, except they were not assigned to the instructor that trained them. The evaluators were not told which group the participant was assigned nor the type of training the participant received. The CFIs providing the training to the treatment groups, who receive PBL instruction and scenario-based flight training, were trained in this method of instruction at the Cirrus Design factory training facility at Duluth, MN. The CFIs providing the traditional instruction have been trained on the Cirrus aircraft systems using traditional instructional methods by the lead instructor for extension programs at UND, who is in charge of the instructors providing the Cirrus Design factory training and who is a FAA designated examiner in the Cirrus aircraft.

2. The method of instruction for the treatment group (group 2) was PBL instruction with scenario-based flight training. The method of instruction for the comparison group (group 3) was non-PBL instruction with traditional maneuvers-based flight training. The treatment group received PBL instruction including problem solving-, case study-, and scenario-based instruction. The training syllabus used to guide the training is an accepted FAA/Industry Training Standards (FITS) syllabus for the Cirrus SR22 aircraft. The training includes blended instruction with PBL instructional designs on aircraft systems and 5 flight lessons for approximately 10 hours of flight training using the scenario-based training method.

3. The comparison or non-PBL instruction group also received blended instruction on aircraft system and system operations; however, it only involved traditional FAA ground instruction methods. Traditional FAA instructional methods include the formal and informal lecture, guided discussion, and the demonstration-performance methods. The FAA also recommends that flight-training methods of instruction include the demonstration-performance or telling-and-doing technique in maneuver-based flight training. Instruction in aircraft systems knowledge was provided by a MS PowerPoint presentation on CD-ROMs or from the Internet. A pre-FITS

version of the Cirrus SR22 aircraft-training syllabus was used for this training; thus, it did not involve the use of PBL instruction. Again, the flight training was offered in 5 lessons with approximately 10 hours of maneuver-based flight instruction.

4. The control or self-study group received no training; but the group was provided the pilot operating handbook for the Cirrus SR22 and appropriate operations manuals. The control was also provided access to the ATD for self-study up to 10 hours and permitted to ask instructor assigned to the study specific aeronautical knowledge and aircraft systems questions.

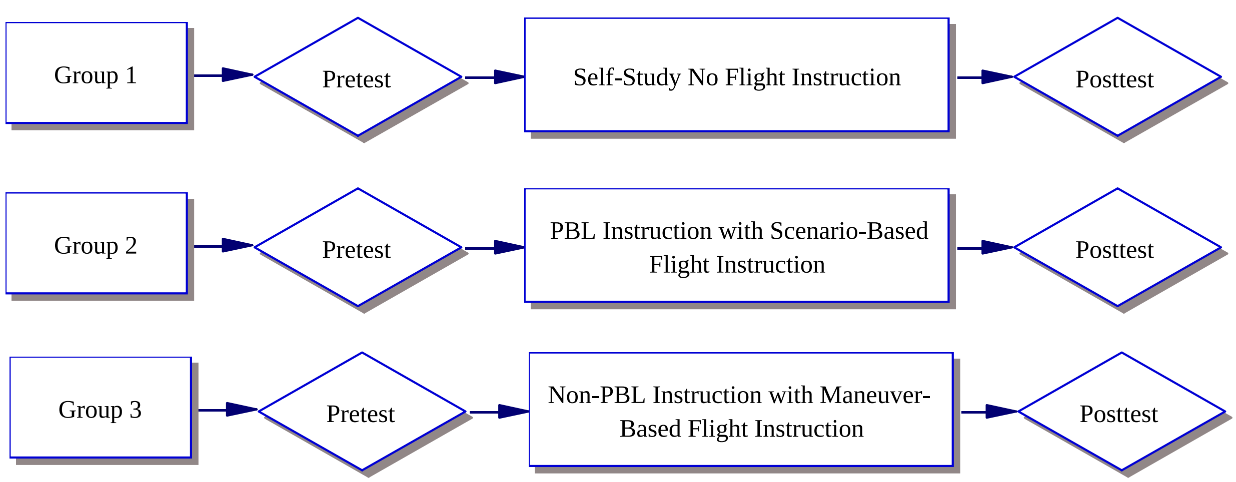
CHAPTER 4: PRESENTATION AND ANALYSIS OF THE DATA

A. A pretest-posttest control-group experimental research design (see figure 4) was used to determine if problem-based learning (PBL), when used in blended instruction, significantly enhances the development and transfer of higher order thinking skills (HOTS) in aviation education. The study compared the effects of the two methods of instruction on the aeronautical decision-making (ADM) skills and the quality of the subsequent pilot judgments. The study answered the following research questions:

> 1. What is the effect of the method of instruction on upper-division college students' development and transfer of HOTS?
>
> 2. Does problem-based instruction improve pilot judgment, automation management, situational awareness, and performance compared to instruction that is not problem based?

B. The experiment, shown in Figure 4, attempted to determine if the null hypothesis that claims PBL does not significantly enhance HOTS and subsequent quality of pilot judgments and decision-making could or could not be rejected.

Experimental Research Design

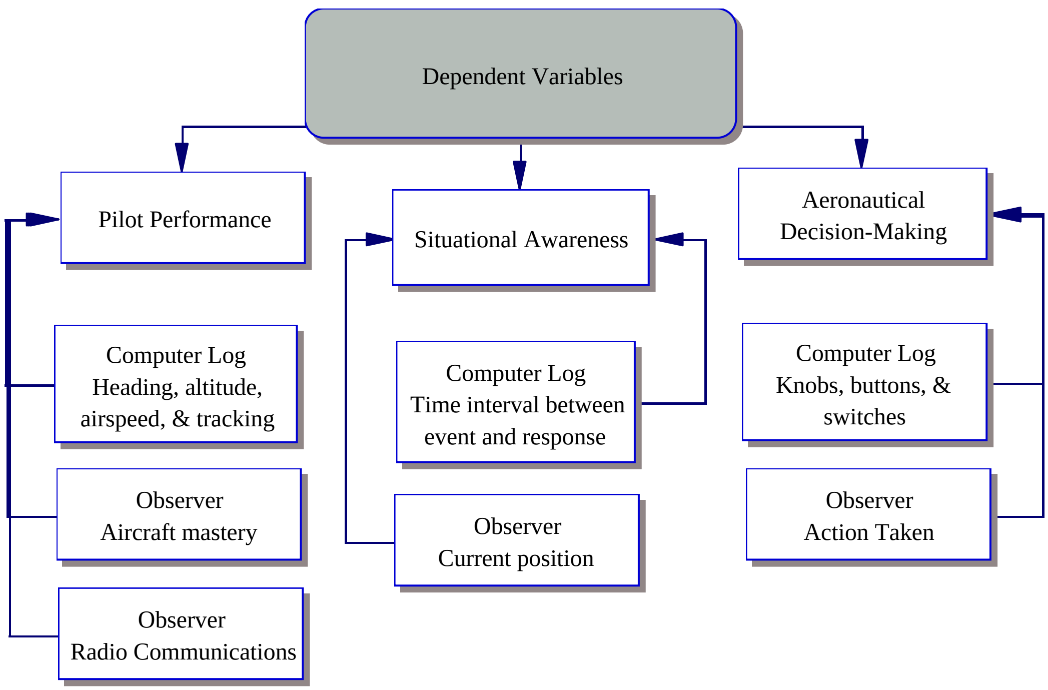


Group 1: Control Group (Self-Study)
Group 2: Treatment Group (Problem-Based)
Group 3: Alternate Treatment Group (Maneuver-Based)

Figure 4: Pre-Posttest Control-Group Experimental Research Design

C. The experimental treatment was the method of instruction—blended PBL, while the alternate treatment utilized blended non-PBL. The three categories of dependent variables were pilot performance, situational awareness, and aeronautical decision-making. Several dependent variables indicated the effects of the three methods of instruction on each of the three categories of dependent variables (see Figure 5). The specific dependent measures analyzed include (a) heading, (b) airspeed, (c) altitude, (d) written assessments, and (e) in-flight situations involving events and radio calls. For all statistical tests, one-way analysis of variance (ANOVA) was used to calculate the *F* ratio and an alpha level of .05 was used.

Variables for Data Collection



Note: The dependent variables that will be examined are listed in the second row while the dependent variables and the source of the data influencing each of the three categories are listed in the column under the dependent variable.

Figure 5: Defining and Obtaining the Data

D. Data Analysis

1. The descriptive statistics for each of the groups were computed and analyzed. The data were obtained from the pre- and posttest assessment of the pilot performance, situational awareness, and aeronautical decision-making skills. In this study, the analysis was organized and described in four parts. The four parts are descriptive, pilot performance, situational awareness, and aeronautical decision-making statistical analyses. The descriptive analyses are subdivided into demographics and measures of homogeneity including intelligence, ability to complete pilot training, higher order thinking awareness, pilot performance, situational awareness, and aeronautical decision-making skills.

2. Descriptive statistics on both the pre- and posttests identified the differences within and between the groups, demographics of the groups, and the existence of outliers and the deviations

from expected data. The existence of outliers would be particularly troublesome in this study because small groups were used. Outliers' effects are amplified in studies that only use a small group whether the deviation was a result of the participant's lack of interest, illness, or some other factor not related to the intervention. Two individuals in group 2 had over 800 hours of single-engine time; however, this was not found to be a significant difference between the groups ($F = 2.483$, $p = .101$).

E. Descriptive Data

1. The participants were upper-division college students majoring in flight education in a collegiate aviation program. As Table 1 shows, the 33 participants averaged 22 years old and ranged in age from 20 to 29 years. Only 31 of participants held FAA commercial pilot certificates with instruments and multi-engine ratings at the beginning of the study; however, the remaining two participants obtained these certificates and ratings before they began the experimental training. Because flight experience is considered by most people to be the primary indicator of pilot ability and competence, it was measured and analyzed in this study. Again, Table 1 shows that the participants in this experiment were low time pilots. Low time pilot experience is typical of individuals in collegian aviation programs although it is not typical for the general pilot population or the population commonly buying new airplanes. Pilot experience will be discussed in chapter 5. The average single-engine land (SEL) flight hours of the participants were 324 hours, and they ranged from a low of 125 to a high of 980 hours. Group 2 averaged more SEL time than groups 1 and 3 (with 425 compared to 350 and 189 hours, respectively); however, an analysis of variance (ANOVA) showed that this difference was not significant. No significant differences within or between the groups were found for age, certificates held, or SEL flight time as well (see Table 1).

Table 1. Participant Descriptive Data

		Age			Certificate			Fight Time—SEL			
	Size	*M*	Min	Max	C/I/M	CFI	CFII	*M*	*SD*	Min	Max
Group 1	*n*=10	21.70	20	24	10	9	4	350.20	167.31	177	485
Group 2	*n*=12	22.25	20	27	11	9	4	425.00	394.92	145	1356
Group 3	*n*=11	21.91	20	29	10	3	1	189.36	42.60	125	260
Total	*N*=33	21.97	20	29	31	21	9	323.79	268.93	125	1356

2. To determine that there were no significant differences between the groups at the beginning of the experiment at an alpha level of .05, three additional measurements were administered. These additional measurements included (a) the Wechsler Adult Intelligence Scale III, vocabulary portion only, (vocabulary); (b) Mental Rotations Test (MRT-A); and (c) Higher order Thinking Awareness Test (HOTA). The vocabulary test measured the intelligence of the

participants in a general descriptive manner without attempting to normalize or adjust for regional differences. The mean intelligence of each group was compared to determine that each group possessed similar levels of intelligence—similar learning abilities. The MRT-A test, used by the United States Air Force to predict a pilot applicant's ability to complete undergraduate pilot training, was used to indicate the participant's abilities to learn to fly. The Higher order Thinking Awareness test (HOTA), a modified version of Schraw and Dennison's (1994) Assessing Metacognitive Awareness survey, was used to indicate the participant's higher order thinking awareness. Collectively, these measurements indicated whether or not preexisting differences between groups were present.

3. Table 2 illustrates the in-group and between-group difference for the vocabulary (Wechsler Adult Intelligence Scale III), rotation (Mental Rotations Test-A), and HOTA (Higher order Thinking Awareness) measurements. An ANOVA of the vocabulary portion of the Wechsler Adult Intelligence Scale III showed there was no significant difference in intelligence between the groups $F = 0.887$, $p = .422$. Similarly, there was no significant difference in the participant's ability to complete pilot training and in higher order thinking awareness between the groups, $F = 0.419$, $p = .661$ and $F = 0.646$, $p = .531$, respectively.

Table 2. Pretest Statistical Significance of Vocabulary, Rotations, and HOT Awareness

		Sum of Squares	*df*	Mean Square	*F*	Sig.
Vocabulary	Between Groups	123.411	2	61.705	0.887	.422
	Within Groups	2086.650	30	69.555		
	Total	2210.061	32			
Rotations	Between Groups	21.039	2	10.520	0.419	.661
	Within Groups	752.476	30	25.083		
	Total	773.515	32			
HOT Awareness	Between Groups	0.361	2	0.180	0.646	.531
	Within Groups	8.374	30	0.279		
	Total	8.735	32			

4. Table 3 shows the means and standard deviations of the Wechsler Adult Intelligence Scale III (vocabulary), Mental Rotations Test (MRT-A), and Higher-Order Thinking Awareness Test (HOTA) measurements. The mean score shows that all three measurements were very similar and supports the statistical findings that no significant difference exists between the three groups.

Table 3. Mean and Standard Deviations of the Vocabulary, Rotations, and Higher Order Thinking Awareness Measurements

		Vocabulary	Rotations	HOTA
Pretest	Group 1 (n=10)	41.60 (11.05)	14.10 (5.74)	5.55 (0.436)
	Group 2 (n=12)	46.25 (6.82)	14.33 (4.77)	5.49 (0.617)
	Group 3 (n=11)	45.00 (6.90)	15.91 (4.53)	5.30 (0.497)
	Total (N=33)	44.42 (8.31)	14.79 (4.92)	5.45 (0.522)

Values shown in parentheses are standard deviations while all other values are the means of the variable.

5. The higher order thinking awareness assessment was administered during both the pre- and posttest to measure for preexisting conditions and to measure the change in self-regulation and learning of higher order thinking skills following the training. Measuring the ability to complete pilot training was accomplished by using the mental rotations test (MRT-A). The MRT-A is used by the United States Air Force to screen pilot applicants for entry to undergraduates pilot training. In this case, the MRT-A determined that the participants of each group had similar pilot skills levels; thus each group was equally capable of successfully completing the training. These measurements showed there were no preexisting differences in age, flight experience, certificates and ratings, intelligence, meta-cognitive awareness, and piloting skills.

Table 4. Pretest Statistical Significance of Pilot Performance

		Sum of Squares	*df*	Mean Square	*F*	Sig.
% Correct Clearance	Between Groups	2.003E-03	2	1.001E-03	0.075	.928
	Within Groups	0.400	30	1.332E-02		
% Correct Non-clearance	Between Groups	2.354E-02	2	1.177E-02	1.328	.280
	Within Groups	0.266	30	8.859E-03		
Performance Deviation	Between Groups	8.515E-02	2	4.257E-02	0.133	.876
	Within Groups	9.575	30	0.319		

6. The final step, in determining if any preexisting differences were present, was an analysis of the pretest differences between groups on the dependent variables within each of the three categories of dependent variables. The three categories of dependent variables were pilot performance, situational awareness, and aeronautical decision-making. This was accomplished by administering a pretest and analyzing the dependent variables related to each category. Again, ANOVA were used to make these determinations and the results of analyses are shown in Table 4 (pilot performance), Table 6 (situational awareness), and Table 8 (aeronautical decision-making). Table 4 shows the statistical significance of the pilot performance measurements. None of the pilot performance measurements showed a significant difference between groups on the pretest.

7. Table 5 shows the means and standard deviations of the pilot performance measurements and for heading, altitude, and airspeed deviations. Likewise, none of the pilot performance measurements showed a difference between the mean greater than one standard deviation in the pretest.

Table 5. Mean and Standard Deviations of the Pilot Performance Dependent Measurements

		% Correct Clearance	% Correct Non-Clearance	Performance Deviation
Pretest	Group 1	0.836 (0.134)	0.803 (8.399E-02)	0.972 (0.433)
	Group 2	0.843 (0.106)	0.757 (0.105)	1.088 (0.551)
	Group 3	0.825 (0.106)	0.737 (9.002E-02)	1.075 (0.674)
	Total	0.835 (0.112)	0.764 (9.508E-02)	1.049 (0.549)

Note: Values shown in parentheses are standard deviations while all other values are the means of the variable.

8. Table 6 shows the statistical significance of the situational awareness dependent variable. The situational awareness measurement does not show a significant difference between groups. Table 7 shows the means and standard deviations for the percentage of correct actions in response to radio communications, the number correct actions in clearances and non-clearances, and the number of events noticed used in measuring situational awareness. The measurement indicating situational awareness were correct action in response to radio calls in clearances and outside of the clearance.

Table 6. Pretest Statistical Significance of Situational Awareness

		Sum of Squares	*df*	Mean Square	*F*	Sig.
% Noticed	Between Groups	9.360E-02	2	4.680E-02	0.531	.593
	Within Groups	2.644	30	8.813E-02		
Correct Clearances	Between Groups	9.529	2	4.764	0.264	.769
	Within Groups	540.653	30	18.022		
Correct Non-Clearances	Between Groups	6.303	2	3.152	1.219	.310
	Within Groups	77.576	30	2.586		
Number Noticed	Between Groups	9.848E-02	2	4.924E-03	0.092	.913
	Within Groups	16.144	30	0.538		

9. The dependent variable used to measure aeronautical decision-making includes the percentage of correct judgments and the number of correct judgments. Table 7 shows the mean and standard deviations of this measurement. These measurements show consistent means between groups and no show significant differences between the groups on the pretest for situational awareness measurements.

Table 7. Mean and Standard Deviations of Pretest Situational Awareness Measurements

		% Noticed	Correct Clearance	Correct Non-Clearance	Number Noticed
Pretest	Group 1	0.200 (0.270)	19.70 (4.42)	12.00 (1.05)	0.50 (0.71)
	Group 2	0.278 (0.365)	20.08 (4.44)	11.33 (2.10)	0.58 (0.79)
	Group 3	0.152 (0.229)	18.82 (3.74)	10.91 (1.38)	0.45 (0.69)
	Total	0.212 (0.292)	19.55 (4.15)	11.39 (1.62)	0.52 (0.71)

Note: Values shown in parentheses are standard deviations while all other values are the means of the variable.

Table 8. Pretest Statistical Significance of Aeronautical Decision-Making

		Sum of Squares	*df*	Mean Square	*F*	Sig.
% Correct Judgments	Between Groups	8.979E-03	2	4.490E-03	0.186	.832
	Within Groups	0.726	30	2.420E-02		
% Good Judgments	Between Groups	1.717E-02	2	8.586E-03	0.305	.739
	Within Groups	0.844	30	2.815E-02		

Table 9. Mean and Standard Deviations for Pretest Aeronautical Decision-Making

		% Correct Judgments	% Good Judgments
Pretest	Group 1	0.364 (9.740E-02)	0.339 (0.120)
	Group 2	0.372 (0.175)	0.349 (0.181)
	Group 3	0.403 (0.175)	0.392 (0.185)
	Total	0.380 (0.152)	0.361 (0.164)

Note: Values shown in parentheses are standard deviations while all other values are the means of the variable.

10. Tables 1, 2, 4, 6, and 8 showed that there were no significant differences between the groups on any of the dependent variables measured to indicate pilot performance, situational awareness, and aeronautical decision-making on the pretest. The analysis now focuses on the posttests and changes occurring between the pre- and posttests. Again, an alpha level of .05 was used for all statistical tests.

F. Dependent variables

Analyses of several posttest dependent variables were made to determine the effect of the intervention on the three categories of dependent variables (pilot performance, situational awareness, and aeronautical decision-making). Again, ANOVA were used to measure the statistical significance of the data. A discussion of the analysis of the dependent variables follows. Tables showing the statistical significance are included in this section (Tables 10, 12, and 14).

1. Pilot Performance Data

(1) Pilot performance was assessed in a similar manner to that which is used by the FAA in evaluating pilot performance and qualification. The primary difference between an FAA evaluation and the experimental assessment is the method of tracking data. It is impractical for the FAA examiner to track and log heading, altitude, and airspeed deviation at 1-second intervals as is done by the ATD. Consequently, the FAA examiner observes and evaluates the pilot's performance for deviations beyond established criteria. The training device provides more sensitive performance measurements and more reliable comparison bases. The FAA standards are clearly prescribed in Federal Aviation Regulations (FAR) with minimum performance criteria published in various Practical Test Standard (PTS). Chapter 3 describes the process used to measure pilot performance including (a) deviation from the prescribed heading, airspeed, and altitude, (b) researcher observation of aircraft mastery, and (c) researcher observation of actions in response to radio communications.

(2) Pilot performance was measured as the deviation from the prescribed path for both the pretest and posttest. The three deviation scores were computed including the average heading, average altitude, and average airspeed. Average scores were used because accumulative scores would cause the amount of deviation increases over time. That is, deviation scores were recorded at 1-second intervals. Adding these scores together would cause the score to appear to increase with each passing second. Since the duration of the observation varied between participants, accumulative scores were unusable. Finally, the deviation scores (heading, altitude, and airspeed) were combined to form a performance deviation score. Because the scales for each of the deviation scores were different the score normalized by calculating a percentage of allowable deviation. This calculation used the tolerances allowed as satisfactory performance from the Commercial Practical Test Standard as the standard. The average deviation was divided the allowable deviation. The three deviation scores were recorded by the ATD, calculated in Excel, and resulting performance deviation was analyzed in SPSS.

(3) Additionally, the percentage of correct in clearance responses, percentage of out of clearance responses, and number of procedural errors were analyzed to measure pilot performance. These measurements were collected from researcher observations and were recorded on the scenario worksheets (see Appendixes A and B). They indicated mastery of the aircraft. Table 9 shows the analysis of these observations. The ANOVA only showed significant differences between the groups for the percentage of correct in clearance radio calls but not for the other average deviations and measurements. The percentage of correct in clearance activities was $F = 4.767$, $p = .016$ (see Table 10). The LSD post hoc tests of differences showed group 2 performed significantly better that groups 1 and 3 at $p = .025$ and $p = .008$ respectively, while group 1 and 3 showed no significant difference. The means and standard deviations for these measurements of pilot performance are found in Table 11. Additional, analysis of these measurements is necessary to test the effect of the treatment between the pre- and posttest.

Table 10. Posttest Statistical Significance of Pilot Performance

		Sum of Squares	*df*	Mean Square	*F*	Sig.
% Correct Clearance	Between Groups	7.864E-02	2	3.932E-02	4.767	.016
	Within Groups	0.247	30	8.248E-03		
% Correct Non-clearance	Between Groups	1.826E-02	2	9.132E-03	0.601	.555
	Within Groups	0.456	30	1.519E-02		
Performance Deviation	Between Groups	4.19E-02	2	2.059E-02	0.117	.890
	Within Groups	5.299	30	0.177		

Table 11. Mean and Standard Deviations of the Posttest Pilot Performance Measurements

	% Correct Clearance	% Non-Clearance	Performance Deviation
Group 1	0.761 (9.412E-02)	0.758 (0.132)	0.959 (0.293)
Group 2	0.853 (8.368E-02)	0.738 (8.750E-02)	0.872 (0.522)
Group 3	0.745 (9.515E-02)	0.794 (0.149)	0.909 (0.391)
Total	0.789 (0.101)	0.763 (0.122)	0.911 (0.409)

Values shown in parentheses are standard deviations while all other values are the means of the variable.

2. Situational Awareness Data

(1) Situational awareness was measured by measuring the correct responses in clearances and out of clearances, by counting the number of events noticed, by the percentage of events noticed, and by assessing the participant's knowledge through periodic questions about the airplane's position. These counts and questions measured the participant's awareness of the events and changes occurring during the scenario. Table 12 showed higher-order thinking awareness was significantly differences in the situational awareness measurements (F = 3.606, p = .039). The post hoc tests showed the treatment group did significantly better than the control and alternate treatment groups (LSD p = .034 and p = .032 respectively). The post hoc tests also showed there was no significant difference between groups 1 and 3 (self-study and alternate treatment groups, respectively). Table 13 shows the means and standard deviations of the measures of situational awareness. The mean scores also show group 2 is higher than groups 1 and 3, and the mean scores for groups 1 and 3 are almost the same.

Table 12. Posttest Statistical Significance of Situational Awareness

		Sum of Squares	*df*	Mean Square	*F*	Sig.
Clearance Correct	Between Groups Within Groups	18.121 268.848	2 30	9.061 9.266	1.011	.378
Non-Clearance Correct	Between Groups Within Groups	4.211 132.698	2 30	2.105 4.423	0.476	.626
Number Noticed	Between Groups Within Groups	0.562 37.498	2 30	0.281 1.261	0.225	.800
% Noticed	Between Groups Within Groups	6.481E-03 5.359	2 30	3.241E-03 0.178	0.018	.982
HOT Awareness	Between Groups Within Groups	821.131 3415.531	2 30	410.566 113.851	3.606	.039

Table 13. Mean and Standard Deviations Posttest Measurements of Situational Awareness

		Correct Clearance	Correct Non-Clearance	Number Noticed	% Noticed	HOTA
Pretest	Group 1 Group 2 Group 3	17.00 (3.33) 18.64 (3.32) 17.27 (2.41)	12.80 (2.25) 12.55 (1.44) 13.27 (2.53)	0.60 (0.52) 1.00 (1.41) 0.73 (1.19)	0.283 (0.315) 0.333 (0.471) 0.318 (0.462)	5.563 (0.484) 5.695 (0.376) 5.304 (0.393)
	Total	17.66 (3.03	12.88 (2.08)	0.78 (1.10)	0.313 (0.412)	5.524 (0.437)

Values shown in parentheses are standard deviations while all other values are the means of the variable.

3. Aeronautical decision-making Data

(1) Aeronautical decision-making (ADM) was measured as (a) the number of incorrect responses to the clearance (both in the clearance and outside the clearance), (b) as the percentage of correct judgments, procedural errors, and change in judgment, and (c) as a score on the higher order thinking awareness (HOTA) test. These measurements showed differences between groups; however, only two out of seven measurements showed significant differences between groups with an alpha level of .05.

(2) Table 14 shows the results of ANOVA on the percentage of correct judgments and of good judgments, and the differences in percentage of correct and good judgments, F = 2.933, p = .069, F = 3.485, p = .044, and F = 2.566, p = .094, and F = 3.064, p = .062, respectively. The percentage of good judgments shows significant improvement in judgment, while the percentage of correct judgments and difference in percentage of good judgments shows improvement; however, the latter two measurements were not significant. A closer look at the means for these measurements showed that all four were as expected. That is, the group 1 showed the least improvement or a decline, group 2

showed the greatest improvement, and group 3 showed more improvement than group1 but less than group 3.

Table 14. Posttest Statistical Significance of Aeronautical Decision-Making

		Sum of Squares	*df*	Mean Square	*F*	Sig.
% Correct Judgments	Between Groups	0.185	2	9.243E-02	3.291	.069
	Within Groups	0.946	30	3.152E-02		
% Good Judgments	Between Groups	0.208	2	0.104	3.485	.044
	Within Groups	0.894	30	2.980E-02		
Difference % Correct Judgments	Between Groups	0.182	2	9.103E-02	2.566	.094
	Within Groups	1.064	30	3.548E-02		
Difference % Good Judgments	Between Groups	0.219	2	0.109E-02	3.064	.062
	Within Groups	1.071	30	3.571E-02		

(3) Table 15 shows the means and standard deviations of the aeronautical decision-making measures. These measurements included the number of correct judgments, the percentage of correct judgments, the difference in procedural errors between the pre- and posttest, and the difference in percentage in judgments between the pre- and posttest.

Table 15. Mean and Standard Deviations of Posttest Aeronautical Decision-Making

		% Correct Judgments	% Good Judgments	Difference % Correct Judgments	Difference % Good Judgments
Posttest	Group 1	0.313 (0.198)	0.284 (0.205)	-5.1E-02 (0.169)	-5.56E-02 (0.169)
	Group 2	0.497 (0.168)	0.478 (0.182)	0.1255 (0.142)	0.129 (0.151)
	Group 3	0.406 (0.167)	0.370 (0.123)	3.03E-03 (0.242)	3.03E-03 (0.242)
	Total	0.411 (0.188)	0.383 (0.186)	-3.10E-02 (0.197)	3.10E-02 (0.201)

Values shown in parentheses are standard deviations while all other values are the means of the variable.

G. The pretest-posttest control-group experimental research design showed significant improvements in pilot performance, situational awareness, and aeronautical decision-making when the treatment group was compared to the control and alternate treatment groups. The percentage of correct judgments, an indication of aeronautical decision-making, barely beyond the .05 alpha level and should be considered important. A discussion of results, conclusions, and recommendations will be presented in Chapter 5.

H. Tables 16, 17, and 18 show differences between the pretest and posttest for each of the dependent variables by group. The mean, standard deviation, computed value of the t test, degrees of freedom, and 2-tailed significance for pilot performance measurements are shown in Table 16, for situational awareness measurements are shown in Table 17, and for aeronautical decision-making measurements are shown in Table 18.

1. Table 16 shows the average heading deviation was significantly better on the posttest than on the pretest for the treatment group (t = 2.677, p = .22). No other pilot performance measurement reflected a significant difference between the pretest and posttest results.

Table 16. Paired Samples Differences T-Test for Pilot Performance

	Pretest Means	Posttest Means	Mean (SD)	*t*	*df*	Sig. (2-tailed)
Control Group						
% Clearance	0.836	0.761	-7.534E-02 (0.143)	-1.662	9	.131
% Non-Clearance	0.803	0.758	-4.451E-02 (0.177)	-0.793	9	.448
Heading Deviation	6.752	7.900	-1.148 (5.601)	-0.648	9	.533
Altitude Deviation	44.693	43.553	1.140 (30.127)	0.120	9	.907
Airspeed Deviation	17.94	16.517	1.427 (8.198)	0.551	9	.595
Treatment Group						
% Clearance	0.843	0.853	9.64E-02 (8.503E-02)	0.393	11	.702
% Non-Clearance	0.757	0.738	-1.898E-02 (0.140)	-0.470	11	.647
Heading Deviation	9.335	4.953	4.381 (5.669)	2.677	11	.022*
Altitude Deviation	53.459	94.007	-40.658 (136.219)	-1.034	11	.323
Airspeed Deviation	17.944	11.801	6.170 (10.407)	2.054	11	.065
Alternate Treatment Group						
% Clearance	0.825	0.745	-8.014E-02 (0.144)	-1.840	10	.096
% Non-Clearance	0.737	0.794	5.66E-02 (0.167)	1.121	10	.288
Heading Deviation	10.111	7.110	3.000 (7.243)	1.374	10	.199
Altitude Deviation	77.744	84.227	-6.483 (201.222)	-0.107	10	.917
Airspeed Deviation	14.368	11.747	2.621 (8.816)	0.986	10	.347

Values shown in parentheses are standard deviations. * $p < .05$.

2. Table 17 shows a situational awareness measurement had a significant difference between the pretest and posttest for the alternate treatment group. The number of correct non-clearances responses decreased from the pretest to the posttest for the alternate treatment group (t = 2.316, p = .043).

Table 17. Paired Samples Differences T-Test for Situational Awareness

	Pretest Means	Posttest Means	Mean (SD)	*t*	*df*	Sig. (2-tailed)
Control Group						
Correct Clearance	19.70	17.00	2.70 (6.62)	1.290	9	.229
Correct Non-Clearance	12.00	12.80	0.80 ()2.46	1.018	9	.335
Number of Events Noticed	0.50	0.60	1.00E-01 (1.10)	0.287	9	.780
% of Events Noticed	0.20	0.28	8.33E-02 (0.432)	0.610	9	.557
Higher-Order Thinking Awareness	5.55	5.56	3.7E-02 (0.397)	.295	9	.775
Treatment Group						
Correct Clearance	20.08	18.67	1.42 (6.27)	0.782	11	.451
Correct Non-Clearance	11.33	12.42	1.08 (2.64)	1.419	11	.184
Number of Events Noticed	0.58	0.92	0.33 (1.83)	0.632	11	.540
% of Events Noticed	0.28	0.31	2.78E-02 (0.639)	0.151	11	.883

Higher-Order Thinking Awareness	5.49	5.69	5.50 (11.03)	1.728	11	.112
Alternate Treatment Group						
Correct Clearance	18.82	17.27	-1.55 (5.20)	-0.985	10	.348
Correct Non-Clearance	10.91	13.27	2.36 (3.38)	2.316	10	.043*
Number of Events Noticed	0.45	0.73	0.27 (1.56)	0.582	10	.574
% of Events Noticed	0.15	0.32	0.167 (0.553)	1.000	10	.341
Higher-Order Thinking Awareness	5.30	5.30	2.45E-02 (13.61)	0.006	10	.995

Note: Values shown in parentheses are standard deviations. * $p < .05$.

3. Table 18 shows two paired samples were significantly different for the aeronautical decision-making measurements. Both paired samples involved the treatment group. The percentage of correct and percentage of good judgments improved by 12.5% ($t = 3.045$, $p = .011$) and 12.9% ($t = 2.956$, $p = .013$) respectively (see Table 18).

Table 18. Paired Samples Differences T-Test for Aeronautical Decision-Making

	Pretest Means	Posttest Means	Mean (SD)	*T*	*df*	Sig. (2-tailed)
Control Group						
% Correct Judgments	0.364	0.313	-5.111E-02 (0.169)	-0.958	9	.363
% Good Judgments	0.339	0.284	-5.558E-02 (0.178)	-0.987	9	.350
Treatment Group						
% Correct Judgments	0.372	0.497	0.125 (0.142)	3.045	11	.011*
% Good Judgments	0.349	0.478	0.129 (0.151)	2.956	11	.013*
Aeronautical Decision-Making						
% Correct Judgments	0.403	0.406	3.03E-03 (0.242)	0.042	10	.968
% Good Judgments	0.392	0.370	-2.259E-02 (0.231)	-0.324	10	.753

CHAPTER 5: RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

A. Summary and Discussion of Results

1. The study attempted to determine if the null hypothesis that claims problem-based learning (PBL) offered in blended instruction does not significantly enhance higher order thinking skills (HOTS) and subsequent aeronautical decision-making (ADM) could or could not be rejected. It compared the effects of two methods of instruction for teaching aeronautical knowledge and ADM skills. The study answered the following research questions:

> 1. What is the effect of the method of instruction on upper-division college students' development and transfer of HOTS?
>
> 2. Does problem-based instruction improve aeronautical decision-making, automation management, situational awareness, and pilot performance compared to non-problem based instruction?

2. Discussion of Pretest Analysis

(1) The analysis of the data began with comparisons of the participants' age, certificates and ratings, flight experience, metacognitive awareness, intelligence, and pilot learning ability. None of these comparisons indicated any preexisting differences between the randomly assigned groups. Two variables are worth further discussions. They are the participants' age and flight experience. Both variables are low when they are compared to the general pilot population and the typical pilot buying a technically advanced aircraft (TAA), such as the Cirrus Design SR22. Because the participants' age and flight experience are not typical of the general aviation population or the pilots who are of buyers of new aircraft, the findings of this experiment can only suggest that further research is needed to determine the study's applicability to other specific groups or a wider population.

(2) The examination for preexisting differences between groups used three written tests and a pilot performance pretest. The written test measured general intelligence, ability to complete pilot training, and awareness of higher order thinking. The pilot performance test measured the pilot's ability to control an airplane along a prescribed flight path. Deviations or displacement from the prescribed flight path were captured and analyzed. The deviations involved three parameters (heading, altitude, and airspeed); the three key variables are normally monitored by FAA examiners during pilot performance evaluations. For the experiment, these parameters were captured by the training device rather than by evaluator observation. This provided a more sensitive basis for comparison than the pass/fail measurement used by the FAA examiners. The FAA pass/fail scoring is based on an applicant remaining within the prescribed practical test standards (PTS) for a passing score and failing to stay within the prescribed criteria for a failure. The awareness of higher order thinking skills was measured with the Higher Order Thinking Awareness test. This test indicated the participant's ability to think about his or her own thinking. Again, no significant differences between the groups were found on the pretest.

Collectively, the results from the written and flight performance evaluations reflected that there were no significant differences between the groups before the experiment began.

3. *Discussion of Posttest Analysis*

(1) The posttest analysis also included a pilot performance test and a written evaluation. Table 19 summarizes the measurements obtained from the posttest. It shows the measurements used to indicate each of the dependent variables and the measurements showing significant improvement.

Table 19. Summary of the Posttest between Groups Significant Measurements

Dependent Variables	Sig.
Pilot Performance	
% Correct Clearance	*
% Correct Non-clearance	
Heading Deviation	
Altitude Deviation	
Airspeed Deviation	
Situational Awareness	
Correct Clearance	
Correct Non-Clearance	
Number of Events Noticed	
% of Events Noticed	
Higher-Order Thinking Awareness	*
Aeronautical Decision-Making	
% Correct Judgments	†
% Good Judgments	*
Δ in Number of Procedural Errors	
Δ in % of Correct Judgments	†

Note: † *p* < .07 not statistically significant but note worthy. * *p* < .05.

(2) The intervention produced significant improvements and only four adverse effects on pilot performance evaluation and written test. That is, the treatment group (problem-based learning) did better on all significant measurements of pilot performance, situational awareness, and aeronautical decision-making measurements, and significantly better on at least one measurement of each of the three categories of dependent variables (see Table 19). Significant improvements in pilot performance were found in the percentage of correct responses to flight clearances, in situational awareness, in higher-order thinking skill awareness, and in aeronautical decision-making in percentage of good judgments. Table 19 also shows that improvements were found in two other aeronautical decision-making measurements (percentage of correct judgments and change in the percentage of correct judgments between the pre- and posttest), though they were not significant. Except for two areas (accuracy of non-clearance calls and altitude deviations) the other measurements of pilot performance, situational awareness, and aeronautical decision-making showed improvements; however, they were not significant at the .05 alpha level. These are important findings because the treatment is being compared to the

time-tested non-PBL method of instruction, which has been the standard in aviation training for about 70 years. Any adverse trend would raise concerns about the value of training since it would likely mean that the new training would need to be offered as additional training. This would increase the cost of training and require a cost/benefit study to determine the value of the training.

(3) The significant improvement shown on the written evaluation, higher order thinking awareness test, indicates the potential to see additional improvements in aeronautical decision-making over time. The higher order thinking awareness test was the same test given during the pretest to show the participant's ability to think about one's own thinking. This test provides a direct comparison of the change that had occurred as a result of the intervention. This test showed the PBL group did better than the self-study and non-PBL group. Arguably a greater awareness of thinking skills should result in better aeronautical decision-making as pilots continue to practice their decision-making skills.

(4) The results in the comparison of the situational awareness and the aeronautical decision-making also indicated that the treatment had a significant effect on the PBL group. Significant differences were found in the percentage of good judgments and important differences were found in the percentage of correct judgment. These indicate that the participants in treatment group were more aware of their position or situation than the maneuvers-based and self-study groups. Likewise, the difference in percentage of correct judgments between the pre- and posttest indicated fewer bad judgments or errors. These findings will be discussed more fully in the next section.

(5) The technical problems with the training device also affected the situational awareness assessment. The problem that affected the situational awareness assessment was the problem that eliminated the course track-error measurement. The problem was the loss of the machine's capability to measure the time between the introduction of an event or change and the activation of some action to respond to the event or change. The solution to this problem was the observers' recording of whether or not the participant noticed the event. However, the observers only commented on the length of time it took the participant to notice if the time seemed excessive. More accurate and structured methods were needed. These subjective observations were not usable for analysis, but they were helpful in understanding the captured data.

4. *Discussion of Paired Differences Analysis*

(1) The paired differences were comparisons of the pretest and posttest results within each group. Paired sample t tests were performed on each of the dependent variables (measurements). These analyses provide direct comparisons of pretest and posttest results for each measurement by group. In other words, they show the changes that occurred between the pretest and the posttest. Four of the 36 pairs showed significant differences (see Table 20). The differences included heading deviation, percentage of correct judgments, and percentage of good judgments for treatment group and correct non-clearance responses for the alternate treatment group (t = 2.677, p = .022; t = 3.045, p = .011; and t = 2.956, p = .013; t = 2.316, p = .043; respectively).

(2) The improvements in the heading deviation and percentages of correct and good judgments for the treatment group support the posttest analysis finding that the pilot performance and aeronautical decision-making improved for treatment group. The heading deviation finding indicates that the treatment group controlled the aircraft more precisely along the prescribed route of flight. Likewise, the percentages of correct and good judgments indicate that the treatment group increased judgment accuracy between the pretest and posttest.

Table 20. Summary of Significant Paired Sample Differences

	Pretest Means	Posttest Means	Mean (SD)	*t*	*df*	Sig. (2-tailed)
Treatment Group						
Heading Deviation[a]	9.335	4.953	4.381 (5.669)	2.677	11	.022*
% Correct Judgments[b]	0.372	0.497	0.125 (0.142)	3.045	11	.011*
% Good Judgments[b]	0.349	0.478	0.129 (0.151)	2.956	11	.013*
Alternate Treatment Group						
Correct Non-Clearance[c]	10.91	13.27	2.36 (3.38)	2.316	10	.043*

Note: Values shown in parentheses are standard deviations. [a]A pilot performance measurement. [b]Aeronautical decision-making measurements. [c]A situational awareness measurement. * $p < .05$.

(3) The change in the number of correct non-clearance responses indicates that situational awareness improved for the alternate treatment (maneuver-based) group. Additional research is needed to determine if this improvement in situational awareness was caused by the “glass cockpit” or so other factor/s. Additional research is needed to determine why this result occurred.

5. *Limitations of the Study*

(1) Aircraft control and mastery are evaluated on the three parameters measured in this study—heading, altitude, and airspeed. Pilot performance test was used to measure the pilot’s ability to control an airplane along a prescribed flight path. Typically, when a deviation along one parameter occurs, deviations along the other parameters will occur simultaneously or shortly thereafter. This study did not reflect this tendency. Observation made during the pre- and posttest may explain why this tendency did not occur in the experiment. Participants in both groups elected to engage the autopilot early in the scenario. It should be noted that the objective of transition training is not the same as basic pilot training where the main objective it to develop motor skills. In transition training, the objective is to develop and enhance airplane management and aeronautical decision-making skills. Therefore, techniques or procedures that enhance airplane control and reduce the pilot workload are encouraged. The autopilot provides precise aircraft control and reduces the pilot workload. Thus, aircraft control was being managed by the autopilot while the participant determined the cause of the deviation and corrected it. Whether or not the reduction of the pilot workload contributed to this improvement was not examined in this study, but it would be worth further consideration.

(2) The scenarios were designed to limit autopilot use by introducing events to cause the participants to disengage the autopilot. Often pilot procedural errors committed by the participants were observed by the research assistants when the autopilot was disengaged; unfortunately, the computer-captured data became unusable due to the procedural errors. The research assistants' observations were recorded and the number of procedural errors was analyzed. Using these observations required a compromise to prevent complete data loss.

(3) Some of these results may have been adversely affected by the training device (prototype ATD). That is, the training device was difficult to "hand fly" and tended to lock-up anytime the participant made a very large pitch, bank, or roll command input. Most pilots tend to make large inputs when flying simulators that do not provide feedback pressures to the flight controls. The prototype device did not provide feedback pressures.

(4) The prototype device also had several technical problems that contributed to the participants' difficulty in flying the device. Most of the technical problems were a result of missing functionality of the various aircraft systems. For example, the device was equipped with dual Garmin GNS-430 global navigation systems (GPS) units. The actual units provide full navigation and communication capability. However, in the simulation device the second unit (GPS2) only mirrored the first unit (GPS1). The second unit should have provided numerous planning and monitoring capabilities. It should have also provided navigational information without interfering with the primary navigation provided by the other GPS. This missing functionality and the other missing features simply reduced the usefulness of the automation and caused some distractions. This is a particularly important concern because the nature of technically advanced aircraft is to provide efficient and effective automation. The prototype device had artificial limitations that were distracting.

(5) The size and types of deviation from the prescribed flight path did arouse concerns among the researchers. These concerns centered on the participants' poor course tracking, improper holding pattern entry, improper holding pattern procedures, and poor or no response to events or changes that occurred during the scenarios. Some of these deviations may be related to the prototype flight-simulation device and to the differences between the actual aircraft and the training device. The deviations in part may have resulted from a general lack of training in the proper use of an autopilot. Generally, student pilots are not taught to use the autopilot during initial pilot training, a coupled instrument landing system (ILS) approach is the single exception. Because the scenarios were designed to present significant challenges to the participants, so performance differences can be measured. That is, the prescribed flight path was specifically designed to be difficult. The performance deviations that caused concern among the researchers should have been expected on the both the pre- and posttest evaluations. The difficult design provided a measurable difference between the participants. The research assistants noted these deviations and procedural errors while the computer recorded the magnitude of the deviations. These recordings provided the data needed for analysis.

(6) Additionally, the distance off course or track error was not recorded as originally planned. The capability to record this data was eliminated from the prototype during one of the early updates in order to resolve an unrelated technical problem. This was not discovered until most of the participants had completed the pretest, thus restoring the track error function or using an alternative measurement was not considered practical. This was an important technical failure in the experiment. That is, a participant could maintain the correct heading while not being established on-course. This additional measurement would have reported this deviation and could have improved the quality of the pilot performance assessment.

(7) Because the pretest may have interacted with the experimental treatments, that is, the pretest may have an effect on the posttest results, a follow-on study without a pretest is recommended. The pretest interaction was minimized as much as possible by using two different patterns for the pre- and posttest pilot-performance assessments. The pre- and posttest pilot-performance assessments are discussed in more detail in the next section. The FITS research team is planning to conduct the recommended follow-on studies at several factory-training sites and at Middle Tennessee State University. At the factory training sites, it will be possible to offer the training with and without pretests; however, it will not be practical to include control groups. Therefore, it is important to have the results of this study to compare (a) the posttest difference between groups and (b) the difference between the pre- and posttest within the groups.

(8) Another limitation of this study is the sample size. Several factors lead to the low number of participants studied in this experiment including initial problems getting reliable data from the proto-type simulation device, the use of a single simulation device and the limited availability of the device to meet the student's needs, and student availability. Additional research with larger numbers of participants is needed.

(9) Ultimately, these limitations were simply challenges that did not adversely affect the results of the study. Follow-on and longitudinal studies should seek to get rid of these limitations before attempting to collect data. A production model of the training device should not have these technical difficulties.

6. Summary of Results

The pretest results showed no significant differences between groups in any of the measurements used in the study. These measurements included general intelligence, ability to complete pilot training, awareness of higher order thinking skills, pilot experience, and pilot performance. The posttest results showed significant differences between groups for one dependent variable within each of categories of dependent variable (pilot performance, situational awareness, and aeronautical decision-making). The paired sample analysis supported the posttest results in pilot performance, situational awareness, and aeronautical decision-making. All but four dependent variables analyzed showed improvement although they were not significant at the .05 alpha level. The four dependent variables not showing improvement involved two areas (non-clearance radio responses that accounted for three of the measurements and altitude deviation accounted the other).

B. Conclusions

1. The null hypothesis that the method of instruction would not cause significant differences in the higher order thinking skills has been rejected. The results reflected significant differences in the indicators of pilot performance, situational awareness, and aeronautical decision-making. Additional research should be conducted to answer the questions: (a) “Can these findings be duplicated?” and “Will blended PBL instruction significantly improve aeronautical decision-making in the general pilot population or at least in the typical TAA buyer population?” The key finding in this study may be the significant improvement observed in higher order thinking awareness. In the syllabus selected for the study, the total exposure to the treatment (problem-based learning) designed to develop higher order thinking skills were between 10 to 20 hours. Is 10 to 20 hours enough exposure to cause a behavioral change? This question will require additional study. However, increasing the pilot’s awareness of higher order thinking should lead to long-term effects that will subsequently improve general aviation safety. Additional research is needed to verify this effect as well.

2. The findings provided answers to the two research questions (a) what is the effect of the method of instruction on upper-division college students’ development and transfer of HOTS and (b) does problem-based instruction improve pilot judgment and performance compared to instruction that is not problem based. The findings showed significant improvement in the indicators of performance, when difficult situations and challenges were interjected during the flight. The findings also reflected significant improvements in the indicators of aeronautical decision-making (pilot judgment) and a reduction in the number of mistakes made by the pilot. The posttest results of the experiment also showed improvement in the other measurements of pilot performance, situational awareness, and aeronautical decision-making; however, these results did not showed significances at the .05 alpha level.

3. The findings do not provide a definitive answer to the assertion that current training practices need to be changed to include an emphasis in the cognitive skills needed in aeronautical decision-making and critical thinking. The literature outside aviation clearly indicates that critical thinking, as aeronautical decision-making is referred to outside of aviation, needs both the cognitive skills and the cognitive process. It could be argued that the improvements observed in this experiment occurred as results of better training rather than improving cognitive thinking skills. This assertion will also need additional research.

C. Recommendations

1. The implications of this study on all pilot training are that blended problem-based learning should be tested in non-TAA training programs for possible adoption as the “pilot training standard.” The limitations of this study have been discussed in more detail above; nevertheless, the findings of this study cannot be generalized to the entire pilot population without additional research. The sample size was too small to assume that it would apply to the approximate 600,000 active pilots in the United States. It is apparent that college students seeking a degree in aviation and engaged in aviation education are not typical of the general pilot population. In fact, airline pilot applicants are not required to have college degrees, even though it is preferred. Empirical data on the age, flight experience, and work experience of the pilot buying TAA does not match that of the typical college student targeted for the study. The typical student holds a

commercial single- and multi-engine land certificate and instrument rating, little total flight experience, and little or no work experience.

2. The TAA training standards tested in this study were designed for preparing pilot to transition to a new fully automated aircraft. Transition training does not address the acquisition and development of psychomotor skills typically covered in initial pilot training. In fact, it is assumed that the FAA specified aeronautical knowledge and skills required of a pilot already exist in the pilots who are undergoing transition training to TAA. Additionally, the training syllabus used in this study relies heavily on the proper use and management of the aircraft’s automation. Many non-TAA are not equipped with these levels of automation; however, it can be argued that the training in aeronautical decision-making, including higher order thinking skills, and in the proper use of the installed aircraft equipment, would be beneficial. The final consideration in the design of this training model considers the fact most TAA owners will be flying infrequently. Current FAA policies only prescribe the minimum requirements for periodic flight reviews and recency of experience. A safety study (Bell, Robertson, & Wagner, 1992) found that the average flying time for the nation’s active pilots is less than 10 hours a year. A pilot can meet the FAA’s minimum flight review and recency requirements by only flying 10 hours a year; however, the typical pilot is not able to maintain flying proficiency. In this case, flying proficiency means the pilot’s stick and rudder skills are no longer automated. Automated is defined as being able to perform a task or action directly from long-term memory without having to think about the task or action in conscious or short-term memory. This process allows the driver of an automobile to steer the vehicle within the proper lane while using his or her conscious memory to attend to other duties, for example. The infrequent pilot should benefit the most for this TAA training standard.

3. The methods and strategies for teaching HOTS are being adopted rapidly throughout the aviation training community including providers of non-TAA flight training. One example of a non-TAA training provider is Aero-Tech (Lexington, KY), a company that provides both TAA and non-TAA flight training. Embry Riddle Aeronautical University, Middle Tennessee State University, and University of North Dakota provide both TAA and non-TAA training; however, only Middle Tennessee State University has a FITS accepted FITS syllabus. It is expected this trend will continue. In fact, the latest version of the *Instrument Rating Practical Test Standards* (2004) included some of the language of the FITS approach and requirements for scenario-based evaluations including tasks on pilot decision-making and judgment skills. These standards are being implemented in addition to the traditional knowledge and skills development training rather than instead of it.

4. As various flight-training programs adopt the methods and strategies for teaching HOTS, it is recommended that emphasis be placed on the development and use of PBL instructional materials. The literature suggested that best results in developing higher order thinking skills could be achieved when PBL is integrated throughout the course of study. This means that PBL needs to be used throughout aviation education. Academia, industry, and the FAA need to combine their efforts to develop and implement these materials as well as these new training standards.

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APPENDIX A

SCENARIO 1

SUBJECT ____

DATE ____

TIME OF SCENARIO ____

ORDER OF SCENARIO ON THIS DAY FIRST SECOND

RESEARCH ASSISTANTS CONDUCTING SCENARIO:

Experimenter - ____

Controller - ____

Other - ____

____

PROFILE: This is a day IFR flight on January 10th from KMSP (Minneapolis International) to KFCM (Flying Cloud) in selected aircraft. As much as possible, make all decisions as though this is a real flight, in real weather conditions.

WEATHER: Minneapolis area weather generally 1000 ft ceilings with 3-4 miles visibility with light snow showers. No forecast or reported icing.

ALTERNATE AIRPORT: Redwood Falls with forecast weather 1000/3 with light snow.

NOTAMS: Nothing significant

FILED CLEARANCE: KMSP radar vectors to join V82 FGT V171 PRIOR direct KFCM at 5000.

GROUND OPERATIONS

Subject - Obtains ATIS for MSP (*135.35*) **YES NO WRONG**

Controller: ATIS (*135.35*)
Minneapolis International Airport
Information Bravo
1400 Zulu Observation
Wind Calm
Indefinite Ceiling 1000 *(1841 MSL)*
Sky Obscured

Visibility 2½ miles
Light snow
Temperature - 4
Dew Point - 5
Altimeter 29.98
ILS RWYs 12 Left and 12 Right in use.
Landing and Departing RWYs 12 Left and Right and RWY 4
Contact Clearance Delivery on 133.2 prior to taxi,
Advise on initial contact that you have information Bravo.

Subject – Set altimeter (29.98)	**YES**	**NO**	**WRONG**
- Dials in Clearance Delivery (133.2)	**YES**	**NO**	**WRONG**
- Calls for clearance	**YES**	**NO**	

Controller: CLEARANCE
November 328
Minneapolis Clearance Delivery
You are cleared to the Flying Cloud Airport
Via Radar Vectors
To join Victor 82
To Farmington VOR,
V171 PRIOR direct Flying Cloud
Climb and Maintain 3000 feet
Expect higher 10 minutes after departure
Departure on 124.7
Squawk 0427

Subject - Reads back clearance	**YES**	**SKIP**	**WRONG**	**REPEAT**
_____ Flying Cloud Airport	____	____	_______	_______
_____ Via Radar Vectors	____	____	_______	_______
_____ To intercept Victor 82	____	____	_______	_______
______To Farmington VOR	____	____	_______	_______
______V171 PRIOR	____	____	_______	_______
______Direct Flying Cloud	____	____	_______	_______
______Climb and maintain 3000’	____	____	_______	_______
______Expect higher 10 minutes after departure	____	____	_______	_______
______Departure on124.7	____	____	_______	_______
______Squawk 0427	____	____	_______	_______

(Note to Controller – Check the appropriate response. Yes = subject repeated the item in the readback. Skip = subject did not mention the item in the readback. Wrong = subject repeated the item incorrectly. Repeat = means the subject asked the Controller to give that portion of the clearance again. The Controller should correct if any element is incorrect and/or missing on every clearance throughout the scenario.)

Subject - Sets proper squawk code (0427) **YES** **NO** **WRONG**

- Dials in Ground Control Frequency (121.8 or 121.9) **YES NO WRONG**
- Calls for taxi instructions **YES NO**

Experimenter - Fails Oil Pressure (immediate)

Controller – N328, you are holding short of RWY 12L, when you have completed your run-up, contact the tower when ready for takeoff.

Experimenter- Start Recording (F9 on PFD keyboard)

Subject - Does run-up and sets-up radios **YES NO WRONG**
(Should have Unicom in radio #1 and departure in #2 or a technique of their own)
- Double checks routing entered in GPS **YES NO WRONG**
- Reports no/low Oil Pressure **YES NO**

Pilot Makes Judgment Decision- Correct is to abort the TO. **RIGHT WRONG**

Experimenter – If subject notices and states proper intentions (will not take off) then reset the oil pressure and state "Repairs complete, you are back in position". If not detected, then fail the engine on take off roll.

Experimenter- Stop recording *(after completing repairs or at engine failure)* (F10 on PFD keyboard)
Reposition sim at end of runway if necessary, allow the subject time to verify that he/she is ready for takeoff.

LEG 1

Subject – Contacts Tower
- Dials in Tower Frequency (123.95) **YES NO WRONG**
- Sets departure frequency in radio #2 or stand-by radio (124.7)
- Calls ready for takeoff **YES NO**

Experimenter- Start Recording (F9 on PFD keyboard)

Controller: TOWER
November 328
Minneapolis Tower
Fly RWY Heading,
Cleared for Takeoff

Subject- Repeats revised clearance (2)	**YES**	**SKIP**	**WRONG**	**REPEAT**
_____ Fly RWY Heading,	____	____	________	________
______Cleared for Takeoff	____	____	________	________

Subject - Takes off

- Proper Climb Profile **YES NO**
(110-120 SR22, 105 Mooney) (SR22 request subject state climb speed) (±10 knots)
- Flies RWY Heading (120° ± 10º) **YES NO**

Controller: TOWER
November 328
Contact Departure 124.7

Subject - Subject repeats frequency **YES NO WRONG**

Subject - Selects Departure Frequency (124.7) **YES NO WRONG**
- Contacts Departure **YES NO WRONG**
(Minneapolis Departure, N328 passing _____ for 3000.)

Controller: DEPARTURE
November 328
Minneapolis Departure
Ident

Subject - idents **YES NO**

Controller: DEPARTURE
November 328
Minneapolis Departure
Radar Contact
Turn Left heading 270
Report reaching 3,000

Subject - repeats clearance(4)	**YES**	**SKIP**	**WRONG**	**REPEAT**
______Turn Left	____	____	________	________
______Heading 270	____	____	________	________
______Report reaching 3,000	____	____	________	________

- Turns Left **YES NO**
- Heading 270 **YES NO**
- Reports reaching 3,000 **YES NO**

Subject – Levels off at 3000’ (± 100’) **YES NO**
- Reports level at 3000’ **YES NO**

Controller: DEPARTURE
November 328
Intercept V82
Resume own navigation
Report established

Subject - Repeats clearance	**YES**	**SKIP**	**WRONG**	**REPEAT**
Intercept V82	____	____	____	____
Own navigation	____	____	____	
Report established	____	____	____	
Sets NAV frequency correct (115.7)	____		____	
Sets OBS course correct (159°)	____		____	
Check that GPS course is set correctly (SR22)	____		____	

Subject – Reports established V82 **YES** **NO** **LATE** (> 60 secs.)

Controller: Radio Chatter

- Ignore **YES** **NO**

Experimenter- Stop recording *(after 1 minute in level flight and/or established on V82, which ever occurs last)* (F10 on PFD keyboard)

LEG 2

Experimenter- Start Recording (F9 on PFD keyboard)

Controller: DEPARTURE
Provide this clearance when subject is 12DME from FGT)

November 328
I have a holding clearance for you.
Advise when ready to copy.

Subject - Advises ready to copy **YES** **NO**

Controller: DEPARTURE

November 328
Hold Northwest of the Farmington 339° Radial at 6 DME
On the Farmington 339º Radial
Maintain 3000'
Expect one turn in holding
Report established in holding

Subject - repeats holding clearance (7)	**YES**	**SKIP**	**WRONG**	**REPEAT**
______Hold Northwest	____	____	________	________
______Of Farmington 339 Radial at 6 DME	____	____	________	________
______On the Farmington 339° Radial	____	____	________	________
______Maintain 3000'	____	____	________	________
______Expect one turn	____	____	________	________
______Report established	____	____	________	________

Subject - Begins Turn at 6 DME **YES NO**
Makes Right Turns **YES NO WRONG**

Controller: Radio Chatter

Subject - Reports entering holding **YES NO LATE** (final turn inbound)

Controller (On outbound leg): DEPARTURE
November 328
Upon reaching 6 DME
Resume course to Farmington VORTAC

Subject - Responds **YES NO WRONG REPEAT**

Controller: Radio Chatter (ignore) **YES NO**
Experimenter- Stop recording *(after established on inbound course to Farmington)* (F10 on PFD keyboard)

LEG 3

Experimenter- Start Recording (F9 on PFD keyboard)

Controller (On inbound leg): DEPARTURE

November 328
Crossing 6 DME
Climb and Maintain 4000 feet

Subject – Responds	**YES**	**NO**	**WRONG**	**REPEAT**
Crossing 6 DME	____	___	____	____
Climb and maintain 4000’	____	___	____	____

Controller: Radio Chatter **YES NO**

Subject - Departs Holding and tracks inbound	**YES**	**NO**
- Starts climb at 6 DME	___	___
- Reports leaving 3000’ for 4000’	___	___

Experimenter- Stop recording *(after leveling at 4,000)* (F10 on PFD keyboard)

Experimenter- Pause Sim, cover the screen, and ask:

What is your altitude?	Subject _________	Actual ________
What is your current airspeed?	Subject _________	Actual ________
What is your current position?	Subject _________	Actual ________

In 10 min, where will you be? Subject _________ Actual ________

LEG 4

Experimenter- Start Recording (F9 on PFD keyboard)

Controller: DEPARTURE

November 328
I have an amended clearance for you.
Advise when ready to copy.

Subject - Advises ready to copy **YES NO**
(*If subject does not respond by 3 DME then repeat*)

Controller: DEPARTURE
November 328
Minneapolis Departure
After reaching the Farmington VOR
Cleared V171 PRIOR
Direct STUBR direct FCM
Climb and maintain 5000

Subject - Repeats clearance (6)	**YES**	**SKIP**	**WRONG**	**REPEAT**
______After Farmington	____	____	_______	_______
______V171 PRIOR	____	____	_______	_______
______Direct STUR direct FCM	____	____	_______	_______
______Climb and maintain 5000’	____	____	_______	_______

Subject – After Farmington proceeds V171 PRIOR **YES NO WRONG**
- Initiates climb to 5000 **YES NO WRONG**

Experimenter- Enroute to PRIOR, fail ALTERNATOR #1

Subject – DECISION OPPORTUNITY: Impending failure of avionics. Pilot should advise ATC, declare an emergency, and request vector direct to nearest airport (FCM). Subject should also inquire about current weather, and ask where the nearest VFR weather is located.

- Detects alternator failure YES NO
  (If no, than experimenter should advise subject after 3 minutes)
- Advises ATC YES NO
- Request vector direct FCM YES NO
- Declares emergency YES NO
- Inquires about weather at FCM YES NO
- Inquires about location of VFR weather YES NO

(*Reply to Wx request: 300’ ceiling ½ mile visibility, no VFR in the area***)**

Controller – After 5 minutes, if subject has not taken appropriate action to expedite recovery, than Controller should offer assistance and recommend vectors direct to the ILS RWY 9 at FCM.

Controller: DEPARTURE

November 328
Radar vector to Flying Cloud RWY 10 right Localizer Final Approach Course.
Turn Right Heading 320º
Maintain 5000’

Subject - Repeats clearance (7)	**YES**	**SKIP**	**WRONG**	**REPEAT**
_____ Vector to localizer (RWY 9R)	____	____	_______	_______
_____ Right turn heading 320º	____	____	_______	_______
_____ Maintain 5000’	____	____	_______	_______

Subject –	**YES**	**NO**	**WRONG**	**NA**
- Turns right heading 320 (± 10º)	___	___	______	
- Climbs and maintains 5000’ (± 100’)	___	___	______	
- Dials in localizer frequency (109.7)	___	___	______	
- Idents localizer	___	___		
- Sets up inbound course on OBS (098°)	___	___	______	
- Sets up PFD/MFD and checks GPS routing	___	___	______	___

Experimenter – Stop Recording *(after setting OBS and/or checking GPS rout)* (F10 on PFD keyboard)

LEG 5

Controller: DEPARTURE

November 328
Contact Minneapolis Approach 125.0

Subject –	**YES**	**NO**	**WRONG**
- Repeats frequency change	___	___	______
- Dials in correct frequency (125.0)	___	___	______
- Calls Approach	___	___	

Subject – DECISION OPPORTUNITY: Approach Control “forgets” to descend the pilot for the approach and will keep the Subject at 5000 until STUBR unless Subject requests a lower altitude.

Subject – Requests a lower altitude **YES** **NO**

Experimenter- Pause Sim, cover the screen and ask

What is your altitude?	Subject _________ Actual ________
What is your current Airspeed?	Subject _________ Actual ________
What is your current position?	Subject _________ Actual ________
In 10 min, where will you be?	Subject _________ Actual ________

Controller: APPROACH

November 328
Advise when you have Flying Cloud Information Romeo.

Subject – DECISION OPPORTUNITY: During an emergency, the pilot should ask the controller for current weather.

- Asks Approach for current weather. **YES NO**

Controller – (*124.9*)
Flying Cloud Airport
Information Romeo
1400 Zulu Observation
Wind Calm
Ceiling 300 Overcast
Visibility ½ mile
Light Snow
Temperature -7
Dew Point -9
Altimeter 29.98
ILS RWY 10 right in use.

LEG 6

Experimenter- Start Recording (F9 on PFD keyboard)

Controller APPROACH: Provide vectors that allow intercept of the final approach course approximately 5 miles outside STUBR. When subject is at a level altitude and still on a vector to final (320º heading), provide the following clearance.
November 328, expect a slight delay due to a Baron that has blown a tire on the runway. He will be clear of the runway within 15 minutes. Make a left 360 degree turn.

Subject – Responds and acknowledges clearance. **YES NO**

- Makes left 360 **YES NO WRONG**

Controller – When Subject rolls out of turn, continue with vectors to final. When subject is on dogleg
to final, provide the following clearance: (*Reminder, unless a lower altitude has been requested, keep subject at 5000')*
November 328

Turn Right 060º (*or appropriate heading*)
Cleared ILS RWY 10R Approach
Upon passing STUBR
Contact Flying Cloud TOWER on 118.1
Missed Approach as Published

Subject - Repeats approach clearance (4)	**YES**	**SKIP**	**WRONG**	**REPEAT**
_____Turn Right 060º	____	____	________	________
_____Cleared ILS RWY 9R Approach	____	____	________	________
_____Upon passing STUBR contact	____	____	________	________
_____TOWER 118.1	____	____	________	________

DECISION OPPORTUNITY: Subject requests single freq approach YES NO

Subject – Contacted Tower passing STUBR **YES** **NO**

Controller: TOWER/APPROACH
November 328
What will you final approach airspeed be?

Subject – Says proper final approach speed *(100 knots)* **YES** **NO** **WRONG**

Controller: TOWER
November 328
Be advised, a Cessna ahead of you went missed approach, but the reported visibility is still ½ mile.
November 328
Cleared to land

Subject - Responds **YES** **NO**

DECISION OPPORTUNITY: In this time critical emergency situation, the pilot should continue with the current approach and make it a good one (rather than go missed approach simply because the previous aircraft did).

Subject - Continues current approach **YES** **NO**
Lands **YES** **NO**

Experimenter – Stop Recording *(after landing or established a climb for the missed approach)* (F10 on PFD keyboard)

END OF SCENARIO

APPENDIX B

SCENARIO 2

SUBJECT____

DATE____

TIME OF SCENARIO____

ORDER OF SCENARIO ON THIS DAY FIRST SECOND

RESEARCH ASSISTANTS CONDUCTING SCENARIO:

Experimenter - ____

Controller - ____

Other - ____

____

____

<u>SCENARIO</u>: This is a day IFR flight on January 15th in the assigned aircraft from Flying Cloud Airport (SW side of Minneapolis), to St. Paul Downtown Airport, (NE side of Minneapolis). The aircraft is being taken to KSTP for its annual inspection. As much as possible, make all decisions as though this is a real flight, in real weather conditions.

Filed clearance: KFCM – Minneapolis 2 Departure – FGT – KSTP

Area weather: Ceilings 800 to 1000 ft, Vis 2-5 Miles, with fog and light snow. No reported or forecast icing. Winds light and variable.

Alternate airport: Grand Forks

NOTAMS: None

LEG 1

Weather Information from ATIS (*124.9*)
1400 Zulu Observation
Wind Calm
Ceiling 800 Overcast (1706 MSL)
Visibility 5 miles Fog
Temperature -5 (23ºF)

Dewpoint -7 (20ºF)
Altimeter 29.92
ILS RWY 9 right is in use.
Landing and departing RWYs 9 right and 9 left.
Advise on initial contact you have information Delta

Experimenter- Start Recording (F9 on PFD keyboard) (*monitor PFD screen for start of recording*)

Controller – N328, you are holding short of RWY 27L. After completing your runup, contact Ground for clearance.
(Note to Controller – Check the appropriate response. Yes = subject repeated the item in the readback. Skip = subject did not mention the item in the readback. Wrong = subject repeated the item incorrectly. Repeat = means the subject asked the Controller to give that portion of the clearance again. The Controller should correct if any element is incorrect and/or missing on every clearance throughout the scenario.)

Subject - does run-up **YES NO WRONG**

Controller – *(While subject is accomplishing runup)* N328, the weather is deteriorating, and has dropped to 500 Overcast with 2 miles visibility (fog)

Pilot Makes Judgment- Correct action is to evaluate deteriorating weather at KFCM
- And request updated weather at destination. **YES NO**

Controller – *(If subject requests wx update)* Destination wx: 800 Overcast, Visibility 2-5 miles with light snow.

Experimenter – Pilot should evaluate deteriorating weather in consideration of personal weather minimums. If decision is made to abort the flight, ask subject what his/her personal weather minimums are in this situation, advise that weather has improved to those minimums, and that he/she must still go.

Pilot Calls for Clearance on Ground Frequency (121.7) **YES NO**

Controller Responds:
November 328
You are cleared to the St. Paul Downtown Airport as filed, climb and maintain 6000.
Contact Departure on 125.0, Squawk 2345

Subject- Repeats Clearance **(5)**	**YES**	**SKIP**	**WRONG**	**REPEAT**
____Cleared to St. Paul Downtown as filed	____	____	________	________
____Climb and maintain 6000	____	____	________	________
____Contact Departure on 125.0	____	____	________	________
____Squawk 2345	____	____	________	________

Subject –	**YES**	**NO**	**WRONG**	**NA**
Programs GPS for entire flight IAW clearance (*SR22 only*).	____	___	_______	___
Sets Dept Freq 125.0 in one radio and Tower 118.1 in another.	____	___	_______	___

CONTROLLER – Takeoff clearance:
N328 fly runway heading, cleared for takeoff.

Subject –	**YES**	**NO**
- N328 fly runway heading	___	___
- Cleared for takeoff	___	___
- Proper Climb Profile	___	___
(Cirrus 120 KIAS, Mooney 105 KIAS) (SR22 - have subject state the speed he/she will be maintaining during the climb) (±10 knots).	____	___

Controller – N328 Contact Departure

Subject – Acknowledges freq change and contacts MSP Departure (*125.0*) Y**ES NO WRONG**

Minneapolis Departure, N328 airborne Flying Cloud, passing ________ (altitude) for 6000.

Departure Control
November 328
Minneapolis Departure
Radar Contact
Turn left direct Farmington VOR, climb and maintain 5000’.

Subject - Repeats Clearance (5)	**YES**	**SKIP**	**WRONG**	**REPEAT**
_____Left Turn	____	____	________	________
_____Direct Farmington	____	____	________	________
_____Climb and maintain 5000'	____	____	________	________

Subject – Proceeds direct Farmington	YES	**NO**	**POOR TRACKING**
– Levels at 5000’ (± *100’*)	**YES**	**NO**	(Exceeds ½ scale)

Experimenter – Stop recording (*after level off*) (F10 on PFD keyboard)

Controller: (*6 miles from FGT*)
N328, after Farmington, you are cleared to LDASH intersection via Victor 26. Report established on the airway.

Subject – Repeats clearance:	**YES**	**NO**	**SKIP**	**WRONG**	**REPEAT**
N328 roger, after Farmington cleared to LDASH	____	___	____	_______	________
Via Victor 26	____	___	____	_______	________
Report established on Victor 26	____	___	____	_______	________

LEG 2

Experimenter- Start Recording after subject reaches Farmington VOR (F9 on PFD keyboard)

Subject – Reports established on V26. **YES NO WRONG**

Controller: Departure ***(When subject 1 mile after FGT)***
November 328
Contact Minneapolis Approach 121.2

Subject - Repeats clearance (2)	**YES**	**SKIP**	**WRONG**	**REPEAT**
_____Minneapolis Approach	____	____	________	________
_____121.2	____	____	________	________

Subject: Calls Minneapolis Approach (121.2) **YES NO WRONG**

Minneapolis Approach, N328 level 5000.

Controller: APPROACH
November 328
Roger

Controller: Radio Chatter to another aircraft
Subject ignores. YES NO (Responds) REPEAT

Experimenter- Stop recording (*after radio chatter and before pausing sim*) (F10 on PFD keyboard)

Experimenter- Pause sim, cover the screen, than ask:

What is your altitude?	Subject _________	Actual ________
What is your current Airspeed?	Subject _________	Actual ________
What is your current position?	Subject _________	Actual ________
In 10 min, where will you be?	Subject _________	Actual ________

LEG 3

Controller ***(after subject reaches 5000', is established V26, and 9 miles from LDASH):***
November 328
For traffic spacing,
Make a left 360º turn
Then continue tracking Victor 26 to LDASH.

Experimenter- Start Recording (F9 on PFD keyboard)

Subject - Repeats clearance (2)	**YES**	**SKIP**	**WRONG**	**REPEAT**
______left 360º	____	____	________	________
______continue V-26 to LDASH	____	____	________	________

Subject - turns left	**YES**	**NO**	**WRONG**
- maintains altitude w/in 100 ft	**YES**	**NO**	
- Rolls out of turn on Victor 26 (*071°*)	**YES**	**NO**	**WRONG**

Controller *(While subject is in the turn)*
Attention all traffic
A KingAir on climb-out from STP reported Moderate Icing at 5000'
Icing dissipated above 7000

Subject makes Judgment
Proper decision is to request 4000 or lower. **RIGHT** **WRONG**

Controller – *(If subject requests lower)* **N328 descent and maintain 4000.**
(If subject request higher) **N328 higher altitude not available due to traffic.**

Experimenter- Stop recording (*when subject is re-established on V26*) (F10 on PFD keyboard)

LEG 4

Experimenter- Start Recording (F9 on PFD keyboard)

Controller – *Gives this clearance 6 miles from LDASH :*
November 328
Traffic is backed-up going into STP, I have a holding clearance for you.
Advise when ready to copy

Subject - advises ready to copy **YES** **NO**

Controller: APPROACH
November 328

Hold East
Of LDASH intersection
On Victor 26
Expect two turns in holding
1 minute legs
Report Established

Subject - Repeats Holding Clearance (6)	**YES**	**SKIP**	**WRONG**	**REPEAT**
_____Hold East	____	____	________	________
_____LDASH intersection	____	____	________	________
_____on V-26	____	____	________	________
_____Expect 2 turns	____	____	________	________
_____1 minute legs	____	____	________	________
_____Report Established	____	____	________	________

Subject - Executes proper holding entry (*Teardrop or Direct*)	**YES**	**NO**	**WRONG**
- Sets up inbound course on OBS (251°)	**YES**	**NO**	**WRONG**
- Reports entering holding	**YES**	**NO**	**LATE** (final turn inbound)

Experimenter- Stop recording (*after turning outbound for second turn in holding*) (F10 on PFD keyboard)

LEG 5

Experimenter- Start Recording (F9 on PFD keyboard)

Controller **(while subject is turning inbound on second turn in holding):**
N328
You are next in line for STP

Expect vectors for ILS RWY 32 momentarily

Subject	**YES**	**NO**	**SKIP**	**NA**
Acknowledges radio call.	_____	___	____	
Listens to ATIS	_____	___	____	
Programs PFD/MFD/GPS for appropriate approach	_____	___	____	___

Controller
November 328
Upon reaching LDASH
Maintain heading 050º
Vectors to the ILS RWY 32 final approach course to St. Paul Downtown
Say airspeed you will be using on final approach
Advise when you have information ROMEO

Subject - Repeats clearance (7)	**YES**	**SKIP**	**WRONG**	**REPEAT**
____Upon LDASH	____	____	________	________
____Maintain heading 050º	____	____	________	________
____Vectors ILS RWY 32 final approach course	____	____	________	________
____Says airspeed (100 kts)	____	____	________	________
____Will advise when I have ROMEO	____	____	________	________

Subject - Turns right passing LDASH **YES** **NO**

Subject – Establishes a heading of 050º (± 10) **YES** **NO**

Controller: Radio Chatter

- Ignores **YES** **NO**

Experimenter- Stop recording (*after establishing a heading of 050º*) (F10 on PFD keyboard)

Controller: ATIS (118.35)

St. Paul Downtown Airport
Information ROMEO
1400 Zulu Observation
Wind Calm
Indefinite Ceiling 300 (1005 MSL)
Sky Obscured
Visibility 2 miles
Snow
Temperature -4 (25ºF)
Dewpoint -7 (20ºF)
Altimeter 29.92
ILS RWY 32 in use.
Landing and Departing RWY 32
Advise on initial contact that you have information ROMEO

Subject - Reports receiving information ROMEO **YES** **NO**

Experimenter – *Set in weather for approach. (See next page)*

LEG 6

Experimenter- Start Recording (F9 on PFD keyboard)

Controller: APPROACH

November 328
Fly heading 050º
Descend and maintain 3000'

Subject - Repeats clearance (2)	**YES**	**SKIP**	**WRONG**	**REPEAT**
_____050º	____	____	________	________
_____3000'	____	____	________	________

Subject -	**YES**	**NO**	**SKIP**	**WRONG**	**NA**
- Selects proper frequency (111.5)	____	___	_____	_______	
- Identifies proper freq.	____	___	_____	_______	
- Selects appropriate nav modes	____	___	_____	_______	____
- levels off at 3000' (±100')	____	___	_____	_______	

Controller: Radio Chatter
- Ignores **YES NO**

Experimenter- Stop recording (*after level off*) (F10 on PFD keyboard)

Experimenter- Pause Sim, cover the screen, and ask:

What is your altitude?	Subject _________	Actual ________
What is your current Airspeed?	Subject _________	Actual ________
What is your current position?	Subject _________	Actual ________
In 10 min, where will you be?	Subject _________	Actual ________

LEG 7

Experimenter- Start Recording (F9 on PFD keyboard)

Controller APPROACH ***(As subject crosses over the localizer)***

November 328
Turn left
Heading 290º
Descend and Maintain 2500'
Intercept localizer for ILS RWY 32
Report established inbound on localizer

Subject - Repeats clearance (5) **YES SKIP WRONG REPEAT**

_____Turn left	____	____	_________	_________
_____290º	____	____	_________	_________
_____ Descend and Maintain 2500’	____	____	_________	_________
_____Intercept localizer for ILS RWY 32	____	____	_________	_________
_____Report established (inbound)	____	____	_________	_________

Subject - Sets up inbound course on OBS (323°)	**YES**	**NO**	**WRONG**
- reports established	**YES**	**NO**	**LATE**

Experimenter- Stop recording (F10 on PFD keyboard)

Controller – Attention all aircraft inbound to St Paul—St Paul information Kilo now current wind calm ceiling 200 overcast, ½ mile visibility, altimeter 29.92. Snow increasing.

Subject – Decision Point
Visibility is below approach minimums. Subject should advise controller. **YES** **NO**

LEG 8

Experimenter- Start Recording (F9 on PFD keyboard)

Controller: DEPARTURE

November 328
Hold Southeast of BABCO
On the St. Paul Localizer
Maintain 2500’
Expect one turn in holding
Left hand turns
1 minute legs
Report established in holding

Subject - repeats holding clearance (7)	**YES**	**SKIP**	**WRONG**	**REPEAT**
______Hold Southeast	____	____	_________	_________
______BABCO	____	____	_________	_________
______Localizer	____	____	_________	_________
______Maintain 2500’	____	____	_________	_________
______Expect one turn	____	____	_________	_________
______Left hand turns	____	____	_________	_________
______1 Minute Legs	____	____	_________	_________
______Report established	____	____	_________	_________

Subject- Direct entry at BABCO and turns left (*6.3 DME*) **YES** **NO**

Subject - Reports Established holding **YES** **NO** **LATE** (final turn inbound)

Experimenter- Stop recording (*after reporting established in holding*) (F10 on PFD keyboard)

Controller – *as subject turns inbound in the holding pattern.*
N328, St Paul weather improving—now reporting 300 overcast 1 mile visibility. Say intentions.

Subject – Decision point
Weather is now above approach minimums. Subject request to continue approach. **YES**
NO

LEG 9

Experimenter- Start Recording (F9 on PFD keyboard)

Controller **(When the pilot turns inbound):** APPROACH

November 328
You are cleared for the ILS RWY 32 Approach
Contact tower on 119.1 crossing BABCO

Subject - Repeats approach clearance (3)	**YES**	**SKIP**	**WRONG**	**REPEAT**
_____cleared for the Approach (ILS 32)	____	____	________	________
_____tower on 119.1	____	____	________	________
_____crossing BABCO	____	____	________	________

Subject - Sets in correct tower frequency (119.1)	**YES**	**NO**	**WRONG**
Subject - Calls tower upon passing BABCO (6.3 DME)	**YES**	**NO**	**LATE** (*less than 6.0 outside 6.6*)
	____	____	______

Controller: TOWER

Subject -	**YES**	**SKIP**	**WRONG**
St Paul Tower	____	____	______
November 328			
Report Passing 3 DME			

Subject - Repeats clearance (1)	**YES**	**SKIP**	**WRONG**	**REPEAT**
____ Report Passing 3 DME	____	____	________	________

Subject - reports 3 DME	**YES**	**NO**	**OTHER** *(Outside 3.5-2.5 DME)*

Controller: Radio Chatter

Controller: TOWER

November 328
Cleared to land RWY 32

Subject - Repeats clearance to land	**YES**	**NO**
- Fly the ILS approach within ½ scale deflection (glideslope and localizer)	**YES**	**NO**
- Maintains airspeed within 10 knots (*100 knots*)	**YES**	**NO**
- Lands aircraft safely	**YES**	**NO**

Experimenter- Stop recording (*after full stop*) (F10 on PFD keyboard) (*save data*)

END OF PRACTICE SCENARIO