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Development and Transfer of Higher Order Thinking Skills in Pilots

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DEVELOPMENT AND TRANSFER OF HIGHER ORDER THINKING SKILLS IN PILOTS

by

Charles L. Robertson

A Dissertation Presented in Partial Fulfillment
Of the Requirements for the Degree
Doctor of Philosophy

Capella University
August, 2005
DEVELOPMENT AND TRANSFER OF HIGHER ORDER THINKING SKILLS IN PILOTS

by

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Abstract

The aviation community recognizes a need for at least one order of magnitude improvement in general aviation safety. This improvement would virtually eliminate the primary cause of today’s accidents—human factor errors. This study examined a method of teaching higher order thinking skills and compared it to the traditional method of instruction used in flight education. It used a pretest-posttest control-group experimental research design to compare an example of a blended problem-based learning (PBL) and non-PBL methods of instruction. The results of the experiment showed improvements in all measures and significant improvements in several measures of (a) pilot performance, (b) situational awareness, and (c) aeronautical decision-making for pilots transitioning to technically advanced aircraft (TAA). Additional research is needed to determine the value of this method for other aviation training.
Dedication

I dedicate this paper to my parents, James F. and Catharine E. Robertson, who are equally responsible for this endeavor. My mother instilled in me the value of education and my father instilled the belief that I could do anything I put my mind to do. One taught me that I should obtain my doctorate and the other convinced me that I could obtain it. Thus, it is to my parents that I dedicate this endeavor.
Acknowledgements

I would like to acknowledge a long list of people and I will be presenting the list in the order each person has influenced the pursuit of this degree and the research. It begins with my wife, Rajeana, who has provided unwavering support throughout this process. She and my youngest two daughters, Tawny and Ashley, have sacrificed without complaining. Without their understanding, this study would not have been possible. The next acknowledgements are for the financial support provided by the John D. Odegard School of Aerospace Science and the Aviation Department for allowed the teaching schedules and workload adjustments. The key individuals in the Odegard School include Doctors Bruce Smith, Paul Lindseth, Warren Jensen, and James Dunlop.

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The final acknowledgements are for the support and assistance provided Mary Monette, editor, and my committee. Mary helped span the years between learning to write and writing this paper. She also facilitated the transition from informal to scholarly writing. The committee’s continuous efforts, guidance, and encouragement have made this final step possible. Finally, I would like to offer a special thank you to Doctors Charlotte Redden, Mike Medley, and Keith Johansen for serving on my Comprehensive and Dissertation Committees.
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CHAPTER 1. INTRODUCTION

Introduction to the Study

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 according to Wright is due to pilots continuing to make bad judgments under certain circumstances. This paper will study whether such bad judgments can be reduced and pilot decision-making 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 especially in general aviation. This improvement would virtually eliminate the primary cause of today’s accidents. This study will examine a method of teaching higher order thinking skills as a means to accomplish this order of magnitude improvement.

The educational approach used today in all aviation education, based on (a) analyzing past accidents, (b) identifying accident trends, and (c) developing specific training to counter those trends, 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 causes 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.

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.

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.

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 incorporates the strategies that emphasize HOTS in blended instruction and the other uses traditional aviation instructional methods. In this case, 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.

**Background of the Study**

Currently in aviation, 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.

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 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.

Modern learning theories underlie new teaching methods, which facilitate learning judgment, critical thinking, and decision-making. Kerka (1992) said, “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” (¶ 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.

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. 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. 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.

The FAA recognizes that training in atypical situations is inadequate. According to the authors of the AIH (1999), “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” (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 evaluation in this study.

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 are beginning to recognize and use SBT in their training programs, but only in its simplest form. It could be used so much more effectively, if they incorporated reflective and thoughtful thinking. Air carriers began their effort to improve pilots’ judgment and decision-making skills in the early 1980s when they introduced crew resource management (CRM) training (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.

Primarily, CRM and LOTF 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.

This study focused on initial pilot training. Initial pilot training often takes an individual only to the level of earning a single-engine airplane private pilot license. This allows the individual to fly a single-engine airplane and carry passengers. It does not allow the individual to be paid or compensated in anyway for flying anyone or anything else. Additional certificates and ratings are required to operate the airplane for pay 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.

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 airplane (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. According to Robert A. Wright, Manager, General Aviation and Commercial Division, Flight Standards Service, Federal Aviation Administration (FAA), “If general aviation growth becomes even more pronounced, a major challenge for the [general aviation] community will be to decrease accident rates to maintain and increase public acceptability of general aviation as a form of air travel” (Wright, 2002, p. 4). Currently, general aviation has the highest fatal-accident rate of all of the sectors of aviation (Wright, 2002). Thus, general aviation is the area with the most urgent need for improvement.

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)

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
Development and Transfer of Higher order Thinking

to a fatal accident and 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.

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.

Statement of the Problem

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).

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.

**Purpose of the Study**

The purpose of the study is to determine if problem-based learning 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-
Development and Transfer of Higher order Thinking

ROM, DVD-ROM, Internet, or intranet. The study will compare the effects of two methods of instruction 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.

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.

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.
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.

Definition of Terms

Some of the terms used in this study have specific meaning in aviation, 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.

Blended Instruction. Because the term “blended instruction” can have several meanings
or it can be used in many ways, it is necessary to define how it will be used in this study. Online
instruction may refer to an application of instructional tools (computer-based simulations,
testing, and tutorials) either in the classroom or to instruction delivered at a distance where the
instruction is under the control of or connected to a computer. Additionally, Merriam-Webster Online Dictionary (2004) defines *online* as “connected to, served by, or available through a system and especially a computer or telecommunications system (as the Internet).” Computer-based instruction (CBI) is an example of instructional material delivered to the learner through a computer or telecommunication system. In contrast, a video tape displayed in a classroom by an instructor should not be referred to as online instruction even though the VCR typically has a computer controlling all of the functions of the device. In most cases, the computer used in these devices simply controls the devices and not the instruction. Online instruction delivered by computer includes CD-ROM, DVD, digital clips (video, audio, animation, etc.), Internet, and intranet.

Blended instruction is a term for the delivery of instruction based on the integration of face-based instruction and computer-based instruction. In blended instruction, a significant amount of student learning is achieved through online instruction, resulting in changes to course structure and how/where students allocate their time in mastery of the course content. Blended instruction can be an important vehicle to begin to exploit the potential of technology to improve the quality of instruction, to increase access, to increase the amount of learning, and to maintain or reduce costs. (Instructional Technology Planning Board, 2003, ¶ 1)

*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; 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 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
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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 is defined later.

Assumptions and Limitations

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.

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.

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 private pilot certificate at 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.

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
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population but should be meaningful in determining if the PBL has the potential to improve aeronautical decision making, and it is worthy of additional research.

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.

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.

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 of this study. Decision-making skills will be evaluated against existing Federal Aviation Administration (FAA) performance criteria.
Again, the FAA performance criteria are contained in a set of practical test standards established for each pilot and instructor license or rating.

Nature of the Study

An experimental research design measure the differences in aeronautical knowledge achievement and development of decision-making skills between two methods of instruction: (a) CD-ROM and Web-based PBL instruction coupled with scenario-based flight training and (b) traditional drill and tutorial instruction coupled with maneuver-based flight training. The methods of instruction were selected because the PBL instruction with scenario-based flight training is a new approach being recommended by the FITS research team for TAA, and the traditional instruction with maneuver-based flight training is the current approach being used by those who have not adopted the FITS approach. This study should answer the research hypothesis that there is a significant difference between the decision-making skills for pilots taught using (a) CD-ROM/Web-based PBL instruction with scenario-based flight training and (b) traditional instructional methods with maneuver-based instruction. This would demonstrate that higher order thinking skills are taught more effectively and efficiently using PBL instructional designs in blended instruction.

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, (d) learning theory underlying HOTS development and transfer, and (e)
enhancing learning of HOTS with online tools. The third chapter explains the methodology the study will employ. An experimental research design will be 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

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.

Enhancing Pilot Decision-Making

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.

**Requirements for Teaching Thinking Skills**

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).

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.

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.

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.

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.

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.

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
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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.

Learning Theories Supporting the Development of HOTS

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)

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.

**Behavioral Learning Theory.** 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).

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)

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)
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.

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.


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)

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
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.

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.

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.

Constructivist Learning Theory. 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)

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).

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.
Thus, the situated learning theory is better suited to explaining and supporting the learning of HOTS.

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.

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.
Instructional Designs Supporting HOTS

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.

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).

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).

*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.

*Landamatics Instructional Design*

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.

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.

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.

**Theoretical Underpinnings of Instructional Designs**

Because HOTS employ cognitive processes and cognitive skills, their educational objectives and activities are categorized as part of the cognitive domain. They are also supported by the behaviorism, cognitive, and constructivist-learning theories, as the previous section showed. It seems realistic to examine the learning theories as they collectively apply to cognitive skills, because according to Reigeluth and Moore (1999), Bloom’s higher order thinking skills “are all taught through basically similar methods” (p. 55). It should also be true that, if HOTS are all learned through similar methods, then similar learning theories should support these methods.

Reigeluth and Moore (1999) offer a comparison framework upon which an understanding of each theory can be made and a framework for comparing how each is alike or different from the other. The comparative framework includes (a) the type of learning, (b) control of learning, (c) focus of learning, (d) grouping of learning, (e) interactions for learning, and (f) support for learning. This comparison will examine these six elements.
Comparison Framework

Again, the three instructional designs selected to compare and contrast in this study are (a) collaborative problem solving, (b) anchored instruction, and (c) Landamatics. These designs support learning in the cognitive domain; they are primarily grounded in the cognitive learning and in the information processing theory. Emphasis in these theories is placed on unobservable constructs such as (a) mind, (b) memory, (c) attitudes, (d) motivation, (e) thinking, (f) reflection, and (g) other presumed internal processes, and they reflect the influence of the constructivist principles as well. That is, knowledge is not received from outside, but it is constructed in the learner’s head. Knowledge acquired then is the individual’s interpretation of what the individual perceives. The three designs typically include guided discovery or discovery learning applied in solving or completing a problem or task. They represent examples of the new paradigm of instructional theories for the information age where higher levels of learning are becoming more important and where there is a greater need for customization of the learning experience and much greater utilization of information technology, fellow learners, and other resources for learning (Reigeluth & Moore, 1999). These designs and the new paradigm they represent appear to meet the challenges the current practices in aviation.

While these designs support learning in the cognitive domain and reflect both cognitive and constructivist influences, they represent different approaches to facilitating learning. The differences in these designs provide alternatives from which the instructor may choose to optimize the learning environment for a given situation or to vary the learning environment to promote interest and enhance learner motivation. An examination of their differences should provide insight into their potential use.
Type of Learning. According to Reigeluth and Moore (1999),

The type of learning relates to the purpose of the learning activity and the type of learning [level of learning] involved. In essence, this comparison point is the application of an instructional taxonomy to the content of instruction (that is, to the type of learning or cognitive development desired. (p. 57)

In this case, the learning activity should engage the learner in mental activities that involve the solution of a problem or task, examining and evaluating the solution, then determining the best solution, and the development and transfer of cognitive skills including analysis, synthesis, and evaluation. Figure 1 illustrates Bloom’s levels of learning as they relate to the types of learning.

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comprehension</td>
<td>Analysis</td>
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</table>

Figure 1: Types of Learning Based on Bloom’s Levels of Learning.

All levels of Bloom’s taxonomy of learning are important in aviation education including knowledge, comprehension, application, analysis, synthesis, and evaluation; however, the last three (HOTS) present the greatest instructional challenge because they are more complex and develop slowly over a long period (Haladyna, 1997). Consequently, they will be emphasized. On the other hand, Reigeluth and Moore (1999) suggest analysis, synthesis, and evaluation are only useful in deciding what to teach; they are not useful in deciding what method should be used to
teach them because they are taught using similar methods. Thus, they should be collapsed into a single group, that is, higher order thinking skills.

Several authors, including Cotton (1991) and Kerka (1992), suggest teaching students to solve problems or tasks are an effective strategy for teaching higher order thinking skills. PBL focuses on learning occurring in the context of solving a problem including both lower order and higher order thinking (Reigeluth & Moore, 1999). “The central premise of PBL is that instruction should begin with a problem that is important and relevant to the learners. Learning, for both lower order and higher order thinking, occurs in the context of solving the problem” (Reigeluth & Moore, 1999, p. 66). Thus, all three designs involve knowledge, comprehension, application, and higher order thinking types of learning and differ only in the central theme of the design (Anchored Instruction Theory, n.d.; Instructional Design Models, n.d.; Great Ideas in Education, n.d.; Nelson, 1999; Reigeluth, 1999). Collaborative problem solving emphasizes the role of collaborative learning in solving problems asserting that problems are typically handled in a collaborative manner (Nelson, 1999). In other words, most problems are solved with help from others including family, friends, or co-workers and seldom without some assistance from someone else. Anchored instruction emphasizes the role of the video materials in presenting information rather than using other instructional methods (Kearsley, G., 1996), while Landamatics emphasizes a general method of thinking, thus helping the learner relate the new knowledge to existing knowledge (Landa, 1999). Again, all three are different applications of PBL; hence, they provide the same type of learning including the development and transfer of cognitive skills involving analysis, synthesis, and evaluation.
Control of Learning. Control refers to where along a continuum of learning the instruction falls with teacher-centered instruction at one end and learner-centered instruction at the other (figure 2). Reigeluth and Moore (1999) suggested the control of the learning process refers to “who chooses educational objectives, selects content, determines the instructional strategies to be used, and evaluates learning” (p. 58). It would appear at first glance that the teacher would control most of these elements in the three theories selected in this study; however, in a problem solving environment, the content provided may or may not be used by the learner in solving the problem. It is also likely that additional resources may be sought out by the learner during the process including sources, which were not provided by the teacher. If desired outcomes are established by the teacher and authentic, complex, and ill-structured problems are used, then control of the learning will vary along the teacher- and learner-centered continuum based on the desired outcomes. The amount of learner control will depend more on the requirements of the discipline than on the selection of the specific PBL design (Camp, 1996; Ferguson, n.d.; Problem-Based Learning, n.d.a; Problem-Based Learning, 2001).

If learner control is viewed as the amount of assistance or guidance the learner is provided by the instructional design, then there are differences among the methods. Landamatics instructional design theory does not assume that learners already know how to think logically.
and provides guidance for teaching general methods for thinking. These general methods for thinking can be applied to situations as a method of problem solving. Landa also provides support for structuring the development of these thinking skills from easy to complex and concrete to abstract. Indeed, Landa suggests several approaches to the instruction including beginning with guided discovery to more complex problems using the discovery learning or a combination of the two approaches. Collaborative problem solving also suggests a simple to complex structure; however, this leaves far more of the learning to the group to help each other discover solutions to the problems. The collaborative problem solving method also encourages more collaboration on searching for answers from outside sources. Finally, the anchored instruction attempts to provide more information in the video material and encourages discovering the problem and possible solutions from the video. This method asserts that simple problems can be found by the beginner, and more advanced learners will discover the more complex problems and solutions.

Indeed, learner control does appear to vary among the three selected theories. Landamatics appears to provide the widest range along the continuum while the anchored instruction appears to provide the greatest teacher control. Collaborative problem solving provides the least teacher-control but also provides the least individual learner-control, providing instead group-control.

Focus of Learning. The focus of learning addresses the domain-specific topics of the interdisciplinary problems, which can be represented as intersecting continuums. On the horizontal axis, the topic-oriented extreme exists on one end, while the problem-oriented content occurs on the other (see figure 3). Similarly, the interdisciplinary content appears on one end and
the domain specific extreme exists on the other end of the vertical axis. The content could apply in any quadrant or at each end of the continuum. Since all three of these instructional methods are PBL designs, they support the problem oriented activities and may support either interdisciplinary or domain specific activities or both (Camp, 1996; “Problem-Based Learning,” n.d.b; “Problem-Based Learning,” 2001). However, Reigeluth (1999) suggests that HOTS are not domain specific; hence, the desired content will place the application of all three designs on the interdisciplinary end of the continuum. The interdisciplinary nature of these designs is particularly important in aviation because aviation education incorporates concepts from multiple disciplines including physics, chemistry, and mathematics. Otherwise, it would be necessary to learn HOTS in each and in every discipline involved in aviation; that is, if HOTS were domain specific.

Figure 3: Focus of Learning with Horizontal Topic- and Vertical Discipline-Orientations.

Grouping for learning addresses how learners are grouped—does the instructional design support working individually, in pairs, in teams (three to six), or with others (seven or more) (see figure 4)? Collaborative problem solving emphasizes PBL in a collaborative learning environment. It “provides guidelines on how to organize learning groups and suggests specific
activities to structure their learning experiences, such as the jigsaw method (Aronson, Blaney, Stephan, Sikes, & Snapp, 1978), think-pair-share (Kagan & Kagan, 1994), and Student Teams-Achievement Divisions (Slavin, 1995)” (Nelson, 1999, p. 245). Nelson recommends either the instructor or the learners form small heterogeneous work groups, of at least three and not more than six members. Nelson also recommends only three or four members for projects and a slightly larger number for decision-making groups. Considerable attention is devoted to the collaborative process in Nelson’s collaborative problem solving design. Anchored instruction suggests individuals, teams, or groups; however, its guidance on group work is emphasized. However, it is rather limited and only suggests that students should collaborate to define problems, look for necessary data, and to discuss the solutions (Anchored Instruction Theory, n.d.). Landamatics limits its design to individuals, first teaching the student a general method of thinking, general logic structure, which allows one to mentally handle acquiring, manipulating, and applying knowledge of any content (Landa, 1999; Contrast of the Five Cognitive Instructional Design Theories, n.d.).

Grouping for Learning. Grouping is emphasized in only one of the three designs—the collaborative problem solving design. It provides specific guidance on establishing groups and promoting group learning. The anchored instruction design supports group learning but does not emphasize collaborative learning activities while the Landamatic design limits itself to individual learning environments (Landa, 1999). The optimum design in a specific learning instance may be driven by the intended grouping. On the other hand, the interactions or support for learning may be a factor in this situation as well.
Interactions for Learning. Interactions for learning consider the primary nature of the interaction and include the interactions between the teacher and the student, the student and other students, and the student and the material. Collaborative problem solving and anchored instruction designs primarily focus on the human interactions between students and on the nonhuman interactions between the student and the environment or information. Landamatics primarily focuses on the human interaction between the student and the teacher and on the nonhuman interactions between the student and the information (Landa, 1999; Landamatics Theory for Instructional Design, n.d.).

<table>
<thead>
<tr>
<th>Human</th>
<th>Nonhuman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student-teacher</td>
<td>Student-tools</td>
</tr>
<tr>
<td>Student-student</td>
<td>Student-information</td>
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</table>

Support for Learning. Support for learning provides (a) kinds and levels of support that are given to the learner, (b) kinds of cognitive support that are given by the teacher or the
materials, (c) kinds of resources that are available, and (d) kinds of emotional support that are given. Figure 6 illustrates the support continuums of cognitive and emotional support. The level of support given to the learner varies from strongly teacher-centered to largely group oriented. In the Landamatic instructional design, the primary support is provided by the teacher and not the material. Strong emotional support is also provided. Anchored instruction may include some support from the teacher, but it primarily comes from the material and group members.

Emotional support is provided by the teacher and the group. Collaborative problem solving leaves most of the support to the group, and the teacher only intervenes when the group becomes stuck. Even then the teacher will only offer alternatives to consider and not solutions, leaving the group to explore the alternatives, subsequently discover the possible solutions, and finally to select the best solution. Collaborative problem solving and anchored instruction support cognitive and emotional learning, while Landamatics only supports cognitive learning (Nelson, 1999; Anchored Instruction Theory, n.d.; Landa, 1999). The support for learning element again reflects the common PBL basis of these three designs.

![Figure 6](image-url)

Figure 6: Support for learning Cognitive/Emotional Continuums with Increasing Cognitive Support on the Vertical Axis and Increasing Emotional Support on the Horizontal Axis.
The comparisons provided insight into the instructional designs differences. It also provided insight into how each design might be used to handle a specific learning need. The differences in the instructional designs exist in their grouping and interactions for learning where the effect of the grouping is primarily reflected in the type of support. That is, emotional support provided by group collaboration is emphasized in two of the designs and by the instructor in the other. The instructor can take advantage of these differences in meeting specific instructional challenges.

Examining and analyzing the differences can provide a range of tools for the instructor to choose from in meeting specific learning needs. These designs could be used effectively as alternative tools in a comprehensive learning environment that provides variety while targeting specific learning outcomes. For instance, the Landamatics instructional design could be used to develop basic logical thinking skills if a student lacks or is weak in such skills. This design could also be used to ensure individual learners possess the necessary minimum skill set required in some disciplines, such as aviation. Additionally, it would be useful to employ the collaborative problem solving design in a large classroom where the class is divided into small working groups. This would allow the main body of knowledge to be learned by the smaller groups while freeing the instructor to provide one-on-one or small group instruction to each group in turn. The anchored instructional design would be well suited to distance education settings. It would also be well suited where resources permitted the development and use of the information-rich videodisc. Additionally, it could be used as an alternative to either of the other two designs to add motivation or change to the learning activities to provide variety.
The designs selected are well suited to teaching aeronautical decision-making, a critical component of aviation education, as well as aeronautical knowledge to the application level of learning. The comparison also shows PBL facilitates effective learning that could be customized to meet the individual learner’s need, and it shows these designs eliminate inert learning and promote deeper learning.

The collaborative problem solving, anchored instruction, and Landamatics designs can be effectively integrated into a comprehensive learning environment of any domain. As discussed above, the three designs are variations of PBL designs. PBL is well suited to teaching higher order thinking skills and promotes acquiring a deeper knowledge base that is needed for critical thinking in every domain. This is particularly important for the aeronautical decision-making component of aviation education. That is, Landamatics could be used to introduce higher order thinking skills and to establish a method of examining and handling the mental processes involved in problem solving (Landa, 1999). While anchored instruction could be used to increase interest and to motivate students in areas that are adaptable to the videodisc environment (Anchored Instruction Theory, n.d.), the collaborative problem solving design would be used to address the main body of aeronautical knowledge required in aviation education (Nelson, 1999).

These designs represent more than simple expansions of the current guidance provided by the FAA. The designs incorporate the advancement made in teaching and learning theories and practices over the last seventy years. To this end, they employ PBL techniques to facilitate effective learning that could be customized to meet the individual learner’s needs, they eliminate inert learning, and they promote deeper learning which will be more readily recalled by the
learner (Feguson, n.d.; Camp, 1996; Problem-Based Learning, 2001; Problem-Based Learning, n.d.a; Problem-Based Learning, n.d.b; Problem-Solving, n.d.).

Unanswered Questions

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)

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.

Online Aviation Education

Individualizing instruction to meet the learner’s needs in a large classroom setting is difficult to achieve. The literature clearly states that teaching higher order thinking skills effectively involves customizing the examination and exploration of the mental activity to meet the individual learning needs. Furthermore, the changes in methods of instruction required between the typical pilot training setting and the aviation education setting also represent a challenge to the aviation instructional community. As the online instructional literature shows, online instructional tools represent an opportunity to meet this challenge and to enhance the quality of learning. On the other hand, some educators argue that the value of these online tools has not been adequately tested. This study will compare and contrast the strengths and weaknesses of delivering aviation education programs using online tools in the classroom. Furthermore, this study will address the instructional challenges arising in pilot training as it is provided in an academic setting. While aviation education programs are not the typical setting for pilot training, they are an important segment of the aviation instructional community, and these programs are providing direction in resolving the instructional challenges. Additionally, this environment is providing specific issues needing examination and reasonable limitations for this study.
This study will only address pilot training offered in an academic setting. The issues in this study are the challenges to learning that occur in an academic setting. Typically, this setting involves large class sizes and multiple instructors for the various courses (topics) while the nonacademic 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 study—teaching pilots how to make good decisions.

All of these issues are linked. The methods of instruction needed to teach the components of aviation education are driven by the content, desired outcomes, and the setting within which the instruction is to be offered. For example, in the nonacademic setting utilizing one-on-one instruction, the instructor can easily incorporate instruction to the individual’s need including the objectives, content, learning activities, and assessments for teaching aeronautical knowledge and aeronautical decision-making skills. Scenario-based learning and other problem-based learning (PBL) designs can be included in the informal and guided discussion methods, which are among the methods currently recommended by the FAA (AIH, 1999). The sole instructor can also ensure the learner/pilot has learned the required aeronautical knowledge to the desired level of learning as well as the required aeronautical decision-making skills. The FAA recommends the aeronautical knowledge component be learned to the application level, according to Boom’s Taxonomy (AIH, 1999). In contrast, the academic setting (a) does not lend itself to the use of the informal and guided discussion methods of instruction, (b) relies heavily on the lecture method, and (c) uses multiple instructors in the ground and flight instruction portions of the training.
Consequently, the teacher needs to incorporate other instructional methods that emphasize student engagement in the learning process, provide for individual learning differences and styles, and enhance the development and transfer of the cognitive skills involved in aeronautical decision-making. This study will show through examining other studies that online tools can be used in face-to-face settings to supplement the lecture method typically used in classroom instruction to meet these instructional needs.

Key Research in Online Instruction

The key research findings for this study focus on studies involving online instruction. Because there are considerably more studies in other disciplines than in aviation reported in the literature about online instruction, this review will examine the literature from these other disciplines. As a result of the problems discussed below, (a) controversy over the no significant difference studies, (b) the issues presented in the Clark and Kozma debate, and (c) the absence of studies examining CD and DVD-based instruction, this study will base its comparisons on Chickering and Gamson’s (1987) seven principles of good practice including (a) encourages contacts between students and faculty, (b) develops reciprocity and cooperation among students, (c) uses active learning techniques, (d) gives prompt feedback, (e) emphasizes time on task, (f) communicates high expectations, and (g) respects diverse talents and ways of learning. Their seven principles of good practice are widely recognized as the basic elements needed in every instructional situational setting to facilitate learning. It can be argued that many other elements are also important in facilitating learning; indeed, aviation is faced with the need to teach higher order thinking skills. Nevertheless, it is generally agreed that the absence of any of their principles will adversely affect good learning; hence, they were chosen as a good basic list. This
The review of the literature in online instruction will examine the nature of the instructional challenge facing aviation education programs, beginning with the methods for teaching thinking skills, then addressing the “no significant difference” phenomenon, and concluding with the value of computer-mediated communications.

**No Significant Difference between Online and Face-to-Face.** The greatest quantity of material addressing the value of online instruction is found in the literature about distance learning and about the “no significant difference phenomenon.” Because the Russell’s (1999) “no significant difference phenomenon” has had such an influence on distance education and because the ensuing debates provide such valuable insights, it is important to mention these despite the challenges to the validity of Russell’s (1999) “no significant difference phenomenon.”

Russell (1999) summarized the debate on the quality of distance education in his book *No Significant Difference Phenomenon.* Russell concluded from his review of the 355 studies and papers that there was no significant difference between quality of face-to-face and distance education. This is important because the studies assessed the value of many online applications in distance education settings and because there are fewer reported instances of online instruction in the classroom. Hence, his findings and the findings of those who debated the “no significant difference phenomenon” should provide solid support for this comparison. Unfortunately, subsequent studies have recorded that many of the findings in the “no significant difference” research were largely flawed, thus rendering many of the conclusions inaccurate or open to debate (Joy & Garcia, 1999).
One such debate is the Clark and Kozma’s great media debate in which Clark asserts that the method, not the media, affects the academic achievement, while Kozma suggests that the media does contribute to the academic achievement. This debate and many others like it are important to this comparison because they have identified the traps other comparisons have fallen into in their studies. For example, technology often facilitates different instruction designs, which have not been implemented in face-to-face settings. The results of a study where different instructional methods are used may mistakenly report online vs. face-to-face differences in achievement due to media while the instructional methods may have contributed to or may have caused the difference instead.

Additionally, some of the discrepancies noted in the “no significant difference” studies may be attributed to comparing apples and oranges, that is, comparing good instruction to bad instruction. Whether or not this is done by design to cause the results to show what the researcher wants it to show is not the question, yet these studies continue to dominate the literature. For instance, it is easy to find many examples of poor online instruction, much of which has simply been converted from someone’s lecture notes into a PowerPoint presentation. When these presentations are compared with gifted and inspired instruction provided by a highly experienced teacher, the comparison will obviously show the face-to-face instruction is significantly better. Conversely, if a well designed and professionally produced online tutorial is compared to a poor classroom instructor’s work, the finding will show the online instruction is superior and often significantly superior. Including many examples possessing the same characteristics described above does not legitimize the study and findings.
Nevertheless, the validity of Russell’s findings is in question (Joy & Garcia, 2000). Resolving this debate may be difficult because educational research is often hampered by ethical or legal constraints. That is, legitimate experimental research may be difficult to accomplish due to the ethical and legal constraints surrounding the use of control groups when a method of instruction is clearly believed to be better. For example, if a research begins to conduct an experiment comparing two methods of instruction where preliminary results show one method is better, is it ethical to continue to withhold the superior method from the other group (Gall, Borg, and Gall, 1996)? In some cases, the question is answered for the researcher by state law or school district rules, which prohibit the continued use of inferior methods when a superior alternative is available. Arguably, the answer may not be simple because preliminary results are misleading, thus the experiment may need to be completed before the conclusion is made.

*Computer-Mediated Communications.* In contrast to the controversy surrounding the “no significant difference” phenomenon, the literature is overwhelmingly supportive of the positive nature of computer-mediated communications (CMC) in education. Indeed, the CMC literature appears to support both Clark and Kozma’s position in the Clark vs. Kozma Great Media Debate. In some CMC studies, the results imply that the media itself causes an improvement in learning. In other cases, the studies imply that academic achievement is enhanced when a new or different method of instruction is facilitated by CMC. Without assessing whether the media or the facilitated methodology causes the improvement, these findings are unusable in resolving the dilemma; however, they show support for CMC itself. CMC is only one online tool available to the instructor in both the face-to-face and the distance settings. As the following discussion will demonstrate, CMC provides a means to improve learner engagement and enhance learning.
Whether or not the media is solely responsible for the improvement in academic achievement or it is, simply the catalyst, which fostered the incorporation of new or improved teaching methods, is not important; implementing best practices is.

A growing body of literature addresses the effect CMC has on learning and education in both the face-to-face and distance education settings. The use of CMC has increased substantially over the last couple of years; in part, this may be caused by cyberspace’s ability to nourish shared enthusiasm. “During the past two years, the amount of time the average Internet user spends online each week has risen from 4.4 hours to 7.6 hours” (Wright, 2000). Singh (1999) suggests e-mail use is an increasingly common form of communication with teachers, other students, family, friends, and acquaintances with more than fifteen percent of the adult population now using it. Wright (2000) suggests the next stage in the continuing development of technology may be tele-immersion. “Tele-immersion will give you the visual [sound and maybe smell] of being in the same room with a person who is actually in another city” (Wright, 2000). Wright also says, “Cyberspace will have reshaped life because it will have kept doing what it has been doing – nourishing shared enthusiasms” (2000). Wright’s assertion that cyberspace “nourishes shared enthusiasms” may reflect the power of the Internet, help explain why people are using the Internet more and more, and explain why this tool is important to education. That is, if the Internet itself (the media) motivates the learner to learn, then learning is enhanced.

The increased use of CMC affects more than enthusiasm. CMC promotes paradigm shifts (the methodology) and increases student access. As the following comments on instruction and learning will show, CMC supports instructional purposes:

It provides electronic mail and real-time chat capabilities, delivers instruction, and facilitates student-to-student and student-to-teacher interactions across a desk or across
the world. These uses are enabling and promoting several paradigmatic shifts in teaching and learning, including the shift from instructor-centered distance education to student-centered distance learning and the merging of informal dialogues, invisible colleges, oral presentations, and scholarly publications into a kind of dialogic (or even multilogic) virtual university. (Berge & Collins, 1995, February)

Benbunan-Fich and Hiltz (1995) suggests CMC systems can be used to overcome temporal and geographical limitations. For example, Asynchronous Learning Network (ALN), a CMC system, supports “anytime/anywhere” interactions and is tailored for educational activities. ALN may be used to expand and enrich case discussions. “Findings indicate that groups working in an asynchronous networked environment produced better and longer solutions to the case study, but were less satisfied with the interaction process” (Benunan-Fich & Hiltz, 1999). Indeed, literature-based courses delivered via CMC can achieve course objectives as well as face-to-face delivery and courses delivered via CMC could provide as good or better student-instructor and student-student communication. Wells’s report (as cited in Card and Horton, 2000) also found, in her review of the literature, that “CMC fostered discussion and increased participation rates…” Card and Horton (2000) sum it up quite well by concluding, “students taking a literature-based course designed on the principles of good teaching, and delivered via CMC can achieve course objectives as well as students taking the course in a face-to-face classroom . . . Taking the course on the Internet allows students greater flexibility and access to coursework.”

Benson and Wright (1999) also answer the question: “can online reading, writing, and research enrich the classroom experience and improve the level of interaction between students and instructors, as well as among students?” They reported online learning gives an excellent opportunity to foster high order thinking skills, time management capabilities, interpersonal communication, and the capacity to process information (Benson & Wright, 1999). Branscum
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(1997) said electronic discourse, including e-mails, offered a voice to some students who might not otherwise be heard. D’Souza, Doucette, and McComb’s (as cited in Card & Horton, 2000) studies reported that computer communication could be better than face-to-face: “individuals who tended to be inhibited by face-to-face dialogues were less inhibited when communicating via computer.” CMC is changing instructional methods including allowing classes to use a fuller range of interactive methodologies, and encouraging teachers and administrators to pay more attention to the instructional design of courses. University administrators are showing increased attention; for example, a University President and three Vice-Presidents have taken a personal interest in the quality of the online courses because these courses can influence prospective students’ opinion of the entire university without the student even visiting the campus. Nonetheless, CMC promotes self-discipline and requires students to take more responsibility for their own learning. CMC applications can be used effectively to facilitate collaboration among students as peers, teachers as learners and facilitators, and guests or experts from outside the classroom (Berge & Collins, 1995, February). Greenhalgh (2001) agreed, “Computer-based self-study modules can create an individualized education.” He continues: “Computer technologies can support a wide range of learning activities which engage students in the continuous collaborative process of building and reshaping understanding” (Fulfilling Its Potential section, ¶ 1).

Williams (2001) suggest that it is not enough to provide simple access to more resources, but that good online instruction must provide these resources in such a way that they are included in a meaningful learning experience. Williams (2001) said, “Online instruction depends, not only on access to more resources and information, but more importantly, on learning experiences that
are structured and facilitated by educators” (Purpose of This Guide section, ¶ 2). Wang (2000), on the other hand, suggest that multimedia tools can be provided by CMC to provide a meaningful learning experience. According to Wang (2000),

One of the most important advantages is that [multimedia] may offer a unique environment for interactivity, learner control, and student interest and motivation. The existence of multimedia and use of related technologies is going to become a common part of our classroom teaching and learning activities. (Introduction section, ¶ 1)

According to Gayeski (as cited in Wang, 2000), “Multimedia is a class of computer-driven interactive communication systems which create, store, transmit, and retrieve textual, graphic, and auditory networks of information.” Sophisticated video and Web technologies have made our schools dynamic environments for anytime communication, anywhere in the world (McCullen, 2001).

The prophecy of CMC dominating the way students and teachers interact in traditional classrooms and becoming a common part of the classroom teaching and learning activities will be moderated by educators’ acceptance of these technologies. Mitra, Hazen, LaFrance, and Rogan (1999) suggested, “The availability of technology does not necessarily suggest its use. The potential user must see a clear advantage to the use of the technology to use it” (Conclusion, ¶ 1). Their findings indicate the future of CMC will rest on early adopters publishing their successes so others can see the advantages. The advantages of CMC are improved communications and interaction between students, between students and the teacher, and between students and online sources/material, which clearly support the long-standing position held by supporters of CBI that such instruction can and does enhance learning.

The key research findings in CMC focused on the challenges facing teaching thinking skills, the controversy over the “no significant difference” studies, the issues presented in Clark
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and Kozma’s debate on media, and the value of CMC. Teaching thinking skills, including analysis, synthesis, and evaluation, effectively involves customizing the examination and exploration of the mental activity to meet the individual learning needs and emphasizing HOTS strategies with PBL methods. CMC provides the instructor a set of tools that meet these needs and avoids the pitfalls of the “no significant difference” controversy. Studies about CMC suggest support for improving academic achievement without addressing whether or not the media or the methodology affects the change. These findings suggest that direct comparisons of online vs. face-to-face are problematic because many of the “no significant difference” studies are flawed, the cause of the improvement in achievement may have been caused by the media or by the methodology facilitated by the media, and CMC has value in engaging the learner and enhancing learning. Hence, this study needs to be based on comparison where the best practices in both environments are compared and on evaluating each media’s ability to support a widely recognized set of best practices: the Chickering and Gamson’s seven principles for good practice in undergraduate education.

Current Practices. 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.

Current practices in aviation education stem from the Federal Aviation Administration’s (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.

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 (FAR 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.

Limitation of the Lecture Method. 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.).

**Student Participation.** 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.

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.
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.

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.

*Challenge of Teaching Aeronautical Decision-Making.* 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.

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. *How Online Instruction Supports Good Teaching Practices.* A direct comparison of current aviation teaching practices between distance and face-to-face delivery would be difficult because
there are no distance aviation-education programs—there are no online aviation education programs that contain a flight-training component. There is one program that claims to have a distant aviation-education program; however, this program does not conduct the flight-training component through distance education. This single example is a collegiate aviation education degree at Everglades College, Fort Lauderdale, Florida, which claims to lead to a professional aviation baccalaureate degree, but it requires the flight training components to be completed in-residence either at Everglades College or in a FAA Part 141 flight school. This arrangement does not involve the primary challenges besetting aviation educators in delivering aviation education at a distance, namely the flight-training component. Similarly, the three undergraduate aviation-management degree programs and the four graduate aviation degree programs currently being offered in distance education settings do not contain pilot training components either. An extensive search of the Internet and personal interviews found there were no examples of distant education aviation programs that include pilot training components.

The literature does not report any comparative studies involving aviation education including online or distance education. Hence, it is necessary to do the comparison on nonaviation education programs as they relate to online vs. face-to-face. The challenges and limitations identified above lead to the question: Are there ways to improve the delivery of aviation education? A comparison of traditional vs. blended instruction will address this question. This comparison will address how well each instructional method implements and supports Chickering and Gamson’s seven principles of good practice. This approach will allow the instructional methods to be evaluated on their ability to promote learning under similar restraints or including the assumption that both examples were developed using good
instructional design by equally talented teachers or designers with similar experience in course development and instruction. These assumptions may not be representative of the current conditions as evidenced in quantity of poor online instructional material and in the limited amount of quality online instruction material. The comparison will address the weaknesses or limitations each method has in supporting good practices. It will show how the one-on-one method of instruction is not always the most effective or efficient method.

Chickering and Gamson (1987) believed in order to foster good learning; good teaching must accomplish the following:

(A) Encourages contacts between students and faculty, (b) develops reciprocity and cooperation among students, (c) uses active learning techniques, (d) gives prompt feedback, (e) emphasizes time on task, (f) communicates high expectations, and (g) respects diverse talents and ways of learning. (¶ 4)

While applying these principles, or applying them well, does not guarantee good teaching or the best possible learning situation, it is unlikely there will be good teaching if any of these principles are missing. The degree to which each of these principles can be implemented should indicate the method’s strength or weakness in providing good teaching. The comparison will cover each principle in turn.

Chickering and Gamson’s seven principles for good practice in undergraduate education is a widely recognized guide to good instruction, though not universally accepted, and using their principles allows the comparison of good teaching practice in both settings. This approach will avoid comparing examples of good instruction in one setting and poor examples in the other. Current practices are often influenced by the ability of the individual teacher regardless of the media. Because the quality of the teacher will influence the quality of instruction as would the quality of the technology delivering the online instruction, this comparison will evaluate the
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face-to-face vs. online methods of instruction and their capacity to implement and support the Chickering and Gamson’s seven principles for good practice rather than specific examples of each.

*Encouraging Contacts between Students and Faculty.* Frequent student-faculty contact in and out of classes is the most important factor in student motivation and involvement. Faculty concern helps students get through rough times and keep on working. Knowing a few faculty members well enhances students’ intellectual commitment and encourages them to think about their own values and future plans. (Chickering & Gamson, 1987, Seven Principles of Good Practice section, ¶ 1)

Traditional institutions claim they immerse their learners in the ideal learning environment, where academics, faculty, and other students surround the learner, but this claim can be challenged. Many studies are showing contact between the faculty and the student can be improved with communications technology including CMC (Card & Horton, 2000; D’Souza, 1991; Doucette, 1993; Fredickson, 1992; Hiltz, 1986; McComb, 1994; Schrum 1992; Wells, 1992; Wiesenberg & Hutton, 1996). For instance, Berge and Collins (1995, March) said, “Teachers in the networked sections interacted more with their students than teachers in the regular sections” (¶ 6).

Contact between students and faculty is not assured simply because the class meets in a face-to-face setting. Indeed, several studies have reflected teacher and student contact is often missing in traditional classrooms with some students. It is easy to observe students who choose not to participate in almost every class. Student and faculty contact is primarily dependent on the instructor’s efforts and ability to initiate and maintain contact. In large lecture halls, CMC may
be the best, most effective, and in some cases the only means of providing contact between the
teacher and student (Card & Horton, 2000). CMC provides an opportunity to draw introverted
students out and engage them in learning activities. Early research recognized CMC as being
able to reach another group of students who rarely participated in face-to-face classrooms. Card
and Horton (2000), citing studies by D’Souza (1991), Doucette (1993), and McComb (1994),
reported computer communication is better than face-to-face because “individuals who tended to
be inhibited by face-to-face dialogues were less inhibited when communicating via computer”
(Computer-Mediated Communication section, ¶3). According to Chickering and Ehrmann
(1996):

[Communication] technologies can strengthen faculty interactions with all students, but especially with shy students who are reluctant to ask questions or challenge the teacher directly. It is often easier to discuss values and personal concerns in writing than orally, since inadvertent or ambiguous nonverbal signals are not so dominant. As the number of commuting part-time students and adult learners increase, technologies provide opportunities for interaction not possible when students come to class and leave soon afterward to meet work or family responsibilities. (Good Practice Encourages Contacts between Students and Faculty, ¶2)

Traditional instructional methods have worked well for many students over the years. Because some students (a) do well in the traditional setting (b) receive the positive support they need, and (c) the learning communities of several disciplines exist within traditional institutions of higher learning, such as the arts, anthropology, humanities, and philosophy; thus the traditional instructional methods and setting are likely to continue to play a vital role in higher education. What will likely not survive are the large lecture halls where student contact with the faculty is limited or nonexistent (Connick, 1997). Connick (1997) said that many of the changes in higher education are being driven by the need to be “easier to access, unconstrained by barriers of space and time, student-centered, and cost-effective” (p. 12). Changing student needs
represents a formidable challenge to those traditional institutions that are unwilling to adapt communication technologies.

Traditional settings provide contact between students and faculty, which works, well for students who are not intimidated by other class members or factors. Large class size diminishes the opportunity for individual contact between students and faculty and inhibited students are likely to be overlooked and not receive the contact they need in this setting. CMC appears to fill the gaps occurring in the face-to-face settings and to work equally well in distance education settings. However, CMC is limited in its ability to provide personal social contact and in fact, provides a different type of contact than students who have not been engaged in CMC may have experienced before.

The central issue in this part of the comparison is encouraging contacts between students and faculty. The CMC studies reviewed in the key research section of this comparison clearly indicated that contact between students and faculty can be enhanced with CMC. The CMC studies did not say that contacts between the students and faculty cannot be established and maintained otherwise, only that the contacts in face-to-face settings can be enhanced with CMC.

*Develops Reciprocity and Cooperation among Students.* Learning is enhanced when it is more like a team effort than a solo race. Good learning, like good work, is collaborative and social, not competitive and isolated. Working with others often increases involvement in learning. Sharing one’s own ideas and responding to others’ reactions sharpens thinking and deepens understanding (Chickering & Gamson, 1987, Seven Principles of Good Practice section, ¶ 2).
It appears that it would be easier to implement a collaborative learning situation in a face-to-face setting rather than in an online setting. Groups can be assigned and students can easily get together; however, barriers may still exist. Classroom layout, limited class time, or student complacency may hamper the effectiveness of this teaching technique. Recent studies reflect collaborative efforts may be enhanced with CMC, allowing students to improve coordination of group projects or other learning activities (Fredickson, 1992; Hiltz, 1988, 1986; Wiesenberg & Hutton, 1996). New coordination tools have evolved over the last couple of years, which improve coordination of projects and papers such as chat rooms, instant messaging, e-mail, list serves, and collaborative features of Microsoft Office products for example, and these tools are not limited to face-to-face settings. Current online technology facilitates collaborative learning in face-to-face and distance settings. Students are able to establish initial contact and coordinate meeting times and locations online using all of the enhancement tools provided by CMC (Wells, 1992). CMC has the additional benefits of extending the learning environment beyond the classroom and allowing students to meet anywhere at anytime (Fredickson, 1992; Harasim, 1991). In the past, the absences of synchronous communication had hampered effective collaborative learning in online settings; however, many synchronous options are now available including chat rooms and instant messaging as mentioned earlier. The face-to-face setting appears to be the most restricted when CMC tools are not used (D’Souza, 1991; Fredickson, 1992).

In contrast to the enhancements promised by online tools for facilitating collaboration, many face-to-face methods can be easily implemented. These methods may be little more than assigning students to a group and assigning a task to be completed by the group. They may also
involve actively teaching students how to work in groups or how to develop team-building skills. One real advantage the online model appears to have is that it can overcome or eliminate the need to be collocated at a given time. This advantage can be important when an expanded learning community is desirable and the expanded community covers several time zones.

Expanded learning communities allow experts from outside the classroom and beyond the local area to be active participants in the collaborative groups without having actually to be present in the classroom. Another clear advantage online tools provide to the classroom is the ability to access information or materials online. This means groups do not need to leave the classroom or meet at another time to gather or review outside materials. This should increase the likelihood that the group will actually get together and collaborate on the learning activity.

*Uses Active Learning Techniques.* Learning is not a spectator sport. Students do not learn much just by sitting in classes listening to teachers, memorizing prepackaged assignments, and offering answers. They must talk about what they are learning, write about it, relate it to experiences, and apply it to their daily lives. They must make what they learn part of themselves. (Chickering & Gamson, 1987, Seven Principles of Good Practice section, ¶ 3)

Teachers and designers can implement effective cognitive support activities in both face-to-face and online learning. It does appear to be more difficult to ensure 100% participation in rehearsal activities in face-to-face settings according to the CMC studies (Hiltz 1993, 1988). Adaptive instruction is much easier to use in computer-based training than it is in classroom instruction (Clark, 1999, p. 31). Clark (1999) suggests ways to stimulate rehearsal including asking meaningful questions with paper-and-pencil exercises and proper delivery format of the question. For example, when the teacher asks a student a meaningful question, the student rehearses the
material; however, when the teacher asks a meaningful question and pauses before calling on an individual student, the whole class rehearses the question. If the teacher wants to ensure every individual student has rehearsed the question, the teacher will need to ask each student to respond. This is better accomplished through an online response or technology supported system.

In the example given above, collaborative learning activities can be monitored more closely if the group meetings are conducted in the classroom while outside materials are being accessed. This arrangement also allows the teacher to be an active participant in the group learning activities. Likewise, online collaborative efforts can be monitored and joined when the teacher provides the chat room or electronic meeting place. Several of these techniques have been used in the aviation courses taught in a collegiate aviation program. One assignment required each group member to write one multiple-choice question on each of the chapters to be covered on the next unit test. Each group was given a website to post the individual inputs and a final composite list of questions. The groups’ composite lists of questions were made available to the entire class. Group and individual performance can be monitored and evaluated. This example allows the class to take ownership of the assessment.

Gives Prompt Feedback. Knowing what students know and do not know focuses learning. Students need appropriate feedback on performance to benefit from courses. When getting started, students need help in assessing existing knowledge and competence. In classes, students need frequent opportunities to perform and receive suggestions for improvement. At various points during college, and at the end, students need chances to reflect on what they have learned, what they still need to know, and how to assess themselves (Chickering & Gamson, 1987, Seven Principles of Good Practice section, ¶ 4).
Online settings may enjoy an advantage in providing prompt feedback. Feedback can be provided to a student instantly, anytime, or anywhere. The same tools the instructor has to support contact with the student are available to send feedback to the student, but the instructor must be careful with this capability. If students expect to receive answers to their emails within hours and they are sending them to the instructor at two or three o’clock in the morning, the instructor will soon find he or she has no time for life outside of work (D’Souza, 1991, Harasim, 1991).

Online tutorials provide a means for presenting content, assessing understanding, and then remediation if desired. Immediate feedback can be provided to each question during the assessment process. Adaptive programming can control the program execution to enhance the learning experience (Alessi & Trollip, 2001; Clark, 1999). However, tutorials do not need to be online or computer based. Content can be manually controlled and includes any media desired. It is simply easier to develop the tutorial for online or computer based applications. Customizing the content to meet individual learner needs is much easier with technology if it is assumed that a single teacher is providing instruction to a class or a large group. Of course, individualized instruction does not suffer from this limitation.

Online testing can provide immediate feedback. Most current online testing programs do not support automatic grading of essay-type questions well and only have limited success with other constructed-type responses (Manzo, 2003). Simple tasks can be done electronically like spelling, grammar, and word counts, allowing the instructor to concentrate on judging the quality of content for constructed responses (“The seven principles of good practice in teaching: Where do instructional technologies fit in,” 2003). This provides a distinct advantage to the online
constructed-type response test despite its inability to grade the answer completely. In the nonelectronic classroom, the teacher would need to deal with the spelling, grammar, and word count manually.

When the tests are manually graded, the results can be posted online so students know how they are doing as soon as the test is graded. Feedback is not limited to grades; it can include any information the instructor wishes to provide to the student (Manzo, 2003). Classroom settings may also provide prompt feedback as well by employing an assistant to grade the test on the spot or by assigning nonteacher led learning activities immediately after a test, allowing the teacher to grade the test and to provide timely feedback. This begs the question whether it is more cost effective to automate the assignment or hire additional faculty and staff.

Manzo (2003) suggested online testing can provide immediate feedback to the students on all types of constructed-response type tests, and the limitations currently imposed on an essay-type test can easily be overcome by the teacher without a large increase in grading workload (2003). The capability to provide immediate, meaningful, and individualized feedback is a strength in online instruction, which enhances the effectiveness of the traditional instruction when employed as a blended solution.

*Emphasizes Time on Task.* Time plus energy equals learning. There is no substitute for time on task. Learning to use one’s time well is critical for students and professionals alike. Students need help in learning effective time management. Allocating realistic amounts of time means effective learning for students and effective teaching for faculty. How an institution defines time expectations for students, faculty, administrators, and other professional staff can
establish the basis for high performance for all. (Chickering & Gamson, 1987, Seven Principles of Good Practice section, ¶ 5)

The critical issue is not the quantity of time on task but rather providing adequate time. In other words, time on task should mean providing adequate time to meet completion standards or to meet the desired outcomes, not simply completing some specified time requirement (“The seven principles of good practice in teaching: Where do instructional technologies fit in,” 2003). Time on task is easier to tackle with online tools and most online tools can automatically track time on task, while non-technology based instruction must be manually tracked. Face-to-face instructors would have the advantage of personally monitoring the time on task; however, adjusting the time to meet the individual learners’ needs would be easier in the online setting (The seven principles of good practice in teaching: Where do instructional technologies fit in, 2003).

Communicates High Expectations. Expect more and you will get more. High expectations are important for everyone—for the poorly prepared, for the unwilling to exert themselves, and for the bright and well motivated. Expecting students to perform well becomes a self-fulfilling prophecy when teachers and institutions hold high expectations of them and make extra efforts. (Chickering & Gamson, 1987, Seven Principles of Good Practice section, ¶ 6)

Chickering and Ehrmann (1996) suggested, “new technologies can communicate high expectations explicitly and efficiently” (7. Good Practice Communicates High Expectations, ¶ 2). If high expectations can be explicitly and efficiently communicated in a written form, why is the printed page less explicit or efficient than some other form of communication? Communicating expectations via online tools should be more effective for the same reasons online tools appear to be a more effective method of instruction than non-online methods. Technology appears to
enhance the ability to motivate learning, and it supports collaboration. Chickering and Ehrmann (1996) suggested:

Many faculty reports that students feel stimulated by knowing their finished work will be “published” on the World Wide Web. With technology, criteria for evaluation products and performances can be more clearly articulated by the teacher, or generated collaboratively with students. (7. Good Practice Communicates High Expectations section, ¶ 3)

It also appears technology provides the ability to illustrate the instruction or to provide the instruction in multiple forms such as pictures, animation video, and audio. Providing instructions in multiple forms supports different learning style. Technology also allows the instructions to be easily modified or updated, which allows the teacher to change the instructions as the need arises. Some of these capabilities are available in the traditional classroom; however, they are simply easier to implement and maintain using online tools. Written expectations handed out at the beginning of a term or unit of instruction may be misplaced by the learner while online tools allow the learner to retrieve them whenever they need to be reviewed or referenced.

Respects Diverse Talents and Ways of Learning. There are many roads to learning. People bring different talents and styles of learning to college. Brilliant students in the seminar room may be all thumbs in the lab or art studio. Students rich in hands-on experience may not do so well with theory. Students need the opportunity to show their talents and learn in ways that work for them. Then they can be pushed to learning in new ways that do not come so easily. (Chickering & Gamson, 1987, Seven Principles of Good Practice section, ¶ 7)

Online instruction is easily adapted to different learning styles (Card & Horton, 2000; Clark, 1999). It would be a mistake to assume different learning styles cannot be implemented without technology. Individualized instruction can be given to students in small groups or in one-on-one
settings or by carefully integrating them into the face-to-face instructional material while multiple modes of instruction can be incorporated into the blended classroom presentations (Clark, 1999). However, it is easier to provide multiple forms of instruction including audio, video, and animation with online tools than without them.

Chickering and Ehrmann (1996) said it best:

Technological resources can ask for different methods of learning through powerful visuals and well-organized print; through direct, vicarious, and virtual experiences; and through tasks requiring analysis, synthesis, and evaluation, with applications to real-life situations. They can encourage self-reflection and self-evaluation. They can drive collaboration and group problem solving. Technologies can help students learn in ways they find most effective and broaden their repertoires for learning. They can supply structure for students who need it and leave assignments more open-ended for students who don’t. Fast, bright students can move quickly through materials they master easily and go on to more difficult tasks; slower students can take more time and get more feedback and direct help from teachers and fellow students. Aided by technologies, students with similar motives and talents can work in cohort study groups without constraints of time and place. (7. Good Practice Respects Diverse Talents and Ways of Learning section, ¶ 2)

Programmed text, indexes, cross-references, and other such markers within printed materials can provide many of the student-centered learning capabilities offered online. Audio, video, and animation can be provided via non-online tools; however, access to the Internet and all of its resources would not be. In learning settings where discovery learning is appropriate and desirable, it is unlikely that the breadth and range of information could be reasonably provided, particularly in multiple forms to accommodate differing learning styles.

This comparison has addressed how the traditional and online methods of instruction implement and support the seven principles of good teaching. This comparison has shown that good teaching can be implemented in either method. When face-to-face instruction cannot be offered one-on-one or in small groups, online tools can be used more effectively to engage
learners and enhance learning. However, it is also apparent that the most effective instruction is a blended approach, which would use the strengths of each method to mitigate the weaknesses of the other.

Summary of the Literature

*Enhancing the Development and Transfer of HOTS*

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.

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.

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.

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.

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.

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 choose from to customize the instruction to the individual learner’s needs within the cognitive theories.

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.
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.

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.

Instructional Designs

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.

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.

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.

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.

*Delivering Aviation Education Online*

This comparison of online vs. face-to-face delivery methods was based in part on (a) a review of literature including the “no significant difference phenomenon” and CMC, (b) the current practices in aviation education, and (c) Chickering and Gamson’s seven principles for good practice. It was designed to identify the strengths and weaknesses of each method of instruction and to avoid the unequal quality of instruction problems found in much of the literature available today that addresses online instruction. It was designed to identify the strengths of each method so they could be used to mitigate the weaknesses of the other. This suggested a blended approach was better than either approach by itself. Aviation education appears to favor a blended approach, especially to effectively and efficiently teach aeronautical knowledge that is usable while flying an airplane and higher order thinking strategies in an integrated manner.

Twigg (2001) offers an interesting perspective on the role of technology in enhancing learning when she wrote: “When we think about how to utilize technology to improve learning, the key is to focus on what we can do with IT [Information Technology] that we cannot do without it” (II. Improving the quality of Student Learning section, ¶ 2). If the question were revised “how can we utilize online tools to improve learning,” then the question would be “what can we do with online tools that we cannot do without these tools.” The answer to this question must be qualified. Online tools, like technology in general, are only necessary when efficiency and effectiveness are needed. In other words, when one teacher is working with a class of fifty
students, technology can provide the means to customize the instruction to the individual learner’s needs. If a team of teachers were available to teach each learner, then the team could customize the instruction to meet the individual’s needs without technology. This is not a realistic approach, but neither is assuming that current technology does not have limitations or constraints. Alessi and Trollip (2001) list many of the constraints the instructional designer must identify and consider in every learning situation including hardware, software, budget, timelines, responsibilities, content, and permissions.

Better instructional methods are needed to teach aviation effectively and efficiently; still these methods must be realistic approaches, and they are needed now. These instructional methods should (a) include instruction that is customized to the individual learner’s needs; (b) use redirection, probing, reinforcement, asking higher order questions, and lengthening wait-time; (c) employ PBL designs including problem solving-based, case studies-based, and scenario-based instruction; and (d) engage the learner in mental activities that involve the solution of a problem or task, examining and evaluating the solution, and then determining the best solution. These methods are needed to improve judgment skills and to reduce the number of pilot-error type accidents, which should result in a reduction of the number of general aviation fatalities.

Pilot judgment training requires a move to learner-centered methods that engages students and enhances learning, including instruction which emphasizes strategies and methods for teaching higher order thinking skills in authentic or real world-based problems. Integrating online instruction with the existing practices appears to be a viable approach to solving the aviation education needs. Online teaching tools can be used to achieve both efficiency and
effectiveness in aviation education settings where large classes prevail. In teaching environments where one-on-one or small group instruction exists, online teaching tools may be useful but will likely be less important than in a large class. Because the cost of technology and acquisition or development cost of the instructional material will be difficult to justify, it is unlikely online instruction will be considered a viable option. Enhancements in the instructional methods used to teach aeronautical decision-making are needed. This comparison has provided insight into ways instruction can be improved in aviation education to meet its instructional needs.

For example, (a) CMC improves contact between students and the teacher, (b) access to the Internet allows improved collaboration because students can work in the classroom when the group is already together, (c) online tools allow interactive computer-based tutorials to be used, (d) online test and surveys can be graded automatically and can provide instant feedback, (e) computer-based instruction can track time on task and allow students to study the material at the time and place of their choosing, and (f) high expectations and instructional material can be communicated more effectively because they can be presented in many formats. Integrating online instruction with the existing practices appears to be a viable solution to the central problem of teaching the basic aeronautical concepts, theories, and facts in the classroom adequately so that this knowledge can be applied in-flight and used in developing the cognitive skills required in aeronautical decision-making.
CHAPTER 3: METHODOLOGY

This study used an experimental research design to determine if problem-based learning (PBL) instructional designs when used in blended instruction significantly enhance the development and transfer of higher order thinking skills (HOTS) in aviation education. The experiment compared the effects of two 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 answered 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 and performance compared to instruction that is not problem based?

The experiment supported the research hypothesis that PBL offered in blended instruction will significantly enhance HOTS and subsequently improve the quality of pilot judgments and decision-making.

Research Design

This study used the pretest-posttest control-group experimental research design to determine the effect the method of instruction has on the development and transfer of HOTS and subsequent pilot judgments, as compared to the effects traditional methods of instruction have on HOTS and pilot judgments. Students from three Gas Turbine Engine (Avit 327) classes offered in a collegiate aviation program were randomly assigned to two groups. The two groups were (a) a treatment group receiving PBL instruction with scenario-based flight instruction and (b) an alternate treatment or comparison group receiving traditional instruction or non-PBL instruction.
Experimental Research Design

The pretest-posttest control-group design (see figure 7) 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. The study is a part of a larger study examining seven different applications of the Federal Aviation Administration (FAA)/Industry Training Standards (FITS) training philosophy for technically advanced aircraft (TAA). 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. 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.

The upper-division college students were volunteers who had completed course work and flight training at a collegiate aviation program toward becoming a commercial pilot. It is not assumed 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 licenses and certificates, years licenses and certificates 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.

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 manufacturer approved 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.

The transition syllabus and instruction for the treatment and alternate treatment were developed by the University of North Dakota Aerospace Foundation (UNDF) for Cirrus Design factory training. The alternate treatment or alternate method of instruction was also developed under the contract to provide the Cirrus Design factory training. The treatment method of instruction was developed under a partnership between the FITS research team and UNDF (UND Aerospace). UND Aerospace received the training contract in October of 2002, after several fatal Cirrus aircraft accidents and numerous 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-training syllabus has served as the model for several subsequent factory-training syllabi.

The instruction for both the 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 flight scenario 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 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 alternative treatment instruction.

Flight instructors continued the transition training by providing a review of the aircraft systems through ground briefing and five flight lessons. 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). Thus, to keep the experiences of the experimental and comparison groups as identical as possible, it was necessary to examine the more similar training rather than the extremes of the current practices in factory training. The more similar training is
the non-PBL instruction and maneuver-based flight instruction and the extreme in the current practice is no training. The treatment group received a version of the FITS recommended training methods, PBL instruction with scenario-based flight instruction, while the comparison group received an alternate treatment, traditional non-PBL instruction and maneuvers-based flight training.

Other constraints imposed on the experiment were the availability of the training equipment and participants. A prototype of an advanced training device (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; with 2 groups, the study will train and test 20 participants. This requires approximately 200 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 will not be available until the beginning of the next term. Under the terms of the grant, the FITS project was required to have the initial study completed by the end of May 2005.

In this study the experimental treatment, independent variable, was the method of instruction—the blended instruction using PBL instructional designs and the comparison group was the group that received the alternative treatment. The alternative treatment was also blended instruction; however, it 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 dependent variable was the academic achievement in HOTS and the subsequent quality of pilot judgment.

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 testing and experimental treatment. 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. Two groups of 10 participants each yields 20 participants. Twenty 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.

Because the pretest may have interacted with the experimental treatment, that is, the pretest may have an effect on the posttest results, a follow-on study without a pretest is being
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recommended. The pretest interaction with the experiment treatment 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.

Research Protocol

Figure 8 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 two groups. The process was (a) to combine the list of volunteers from the three classes into a single alphabetized list, (b) to assign a random number to each individual using the random number function in Microsoft Excel, (c) to deactivate the automatic calculation function so the random numbers will not change, (d) to sort the list by the participants’ random numbers, (e) to assign the top 10 participants to the treatment group, and (f) to assign the remaining 10 participants to the comparison group. Every participant had an equal chance of being assigned to a particular group.

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.

**Research Flow**

*Note:* Both groups will receive 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 8: Research Flow Chart
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. Additionally, measuring performance deviation along a prescribed flight path is used in pilot evaluations to determine if a pilot possesses the minimum skills required by the FAA for pilot certificates and ratings. 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. Scenarios 1 and 2 were divided equally between pretest and posttest evaluations. The scenarios are similar but not identical, and each has a unique set of pre-planned events. 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).

Actual flight evaluation in the Minneapolis, MN area would provide a direct comparison of the prescribed flight pattern’s validity; however, an actual flight in this area would not provide a standardized evaluation because the events and simulated failures could not be duplicated from one flight to the next. In addition, emergency simulation cannot be carried to their natural termination, that is, an actual emergency cannot be declared and forwarded to air traffic controller for the special handling an emergency aircraft would typically receive. This further means the constraints imposed by Federal Aviation Regulations (FARs) must be complied with for the simulated emergency, even though the best course of action, safest action, may require
the deviation in an actual emergency situation. These constraints would increase the subjectivity of the evaluation and could subsequently have an influence on the results.

*Data Collection*

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 9 illustrates how the data will be obtained in the study. The Mooney Bravo simulation will be used for the pretest and the Cirrus SR22 aircraft will be 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 the aircraft targeted for the study. 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.

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 higher certificates and levels of qualification. 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.
Note: The dependent variables that will be examined are listed in the second row while the independent variables and the source of the data influencing each dependent variable are listed in the column under the dependent variable.

Figure 9: How the Data Was Defined and Obtained

The term deviation is used in this paper 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 the other two parameters. Deviation score is defined in this paper 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.

Other indications of pilot performance are (a) the percentage of radio calls the pilot acknowledges against the number of radio calls directed to the pilot, (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 the pilot saw during the simulator flight. The researchers’ observation will be discussed later.

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.

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 Federal Aviation Administration (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.

These data indicate pilot performance, situational awareness, and aeronautical decision-making. The independent variables include (a) heading, (b) airspeed, (c) altitude, (d) written assessments, and (e) in-flight situations involving events and radio calls. The dependent variables include pilot performance, situational awareness, and aeronautical decision-making.

In this study, 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 thereafter through instrument proficiency checks. All participants are instrument rated pilots.

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.
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 a research assistants 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.

A panel of experts rank-ordered the options, the possible courses of action, available to the pilot for each scenario. The score for the pilot’s choice of action was determined by how far down the rank-ordered options the pilot’s choice occurs. Collectively, the deviation scores, length of the time interval between introduction of a situation and the participant’s response, and the pilot’s in-flight decision-making score provide the pilot performance data needed for this study.

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.

*Instructors and Instruction*

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.

The method of instruction for the treatment group (group 1) was PBL instruction with scenario-based flight training. The method of instruction for the comparison group (group 2) was non-PBL instruction with traditional maneuvers-based flight training. The treatment group
received instruction using one or more of the PBL methods 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 8 hours of flight training using the scenario-based training method.

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 8 hours of maneuver-based flight instruction.

Typically, 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.

Timeline for the Research

Participants were recruited for the study and were randomly assigned to the two groups. All participants were briefed on the project, provided a copy of the consent form, briefed on the administrative requirements, and provided the appropriate training materials and access. The content of the consent form was reviewed with the participants before they were asked to sign and return the form to the research team. The solicitation, consent form, and the pre-training briefing explained that their participation was voluntary and the participant may dropout of the study at anytime without a penalty/loss of any kind. The training was conducted when the participants were available, and it did not require class time, interfere with other course work, or with other flight training requirements. Participation is confidential and the names of the participants will not be used in any documents or publications. A preliminary schedule was developed for the study by one of the research assistants. The schedule was developed for each of the participants based on the availability of the participant, instructor, and the ATD. Excess volunteers were placed in the participant pool and informed about their potential use as soon as possible.

The administration of the pretest to all participants took just over two weekends to complete. The pretest was administered before the beginning of training and took approximately one hour. The posttest was administered in the same manner and scheduled immediately after the completion of the flight training. The participants were able to complete the aircraft system and system operation instruction within two weeks. The treatment and comparison groups were
required to demonstrate mastery of the material by passing a test of the material with a 70% or higher.

The experiment was expected to run approximately one and a half months but took three months to complete. The flight-training syllabus was originally designed to be completed in 2 days. When the participant and instructor’s schedules allowed best utilization of the ATD, six participants should have been able to complete the experiment each week. It should have required about four weeks to complete all of the training of the treatment and alternate treatment groups. Best utilization of the ATD was never achieved because the participants were not available. Data collection needed to be completed by May 6, 2005, to prevent the participants from dropout and to prevent the loss of class integrity that will occur at the end of the semester, mid-May. Special arrangements were made with the participants to continue their training and testing through the end of May. Data analysis and reporting were completed within a month.
CHAPTER 4: PRESENTATION AND ANALYSIS OF THE DATA

A pretest-posttest control-group experimental research design (see figure 10) 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 and performance compared to instruction that is not problem based?

Experimental Research Design

Participants randomly assigned to groups.

![Diagram](Figure 10: Pre-Posttest Control-Group Experimental Research Design)

Group 1: Treatment Group
Group 2: Alternate Treatment Group
The experiment attempted to determine if the null hypothesis that claims blended instruction applying PBL does not significantly enhance HOTS and subsequent quality of pilot judgments and decision-making could or could not be rejected.

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

**Figure 11: Defining and Obtaining the Data**

The experimental treatment was the method of instruction—blended PBL, while the alternate treatment utilized blended non-PBL. The dependent variables were pilot performance, situational awareness, and aeronautical decision-making. Several independent variables indicated the effects of the two methods of instruction on each of the dependent variables (see Figure 11).
The specific independent 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.

Data Analysis

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.

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 is 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. To improve the accuracy of the results, outliers were eliminated even though their elimination further reduced the group size.
Descriptive Data

The participants were upper-division college students majoring in flight education in a collegiate aviation program. As Table 1 shows, the 26 participants averaged 22 years old and ranged in age from 20 to 29 years. Only 24 of participants held Federal Aviation Administration (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 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 210 hours, and they ranged from a low of 125 to a high of 350 hours. Group 1 had more SEL time than group 2 (220 and 182 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, licenses held, or SEL flight time as well (see Table 1).

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.

Table 1. Participant Descriptive Data

<table>
<thead>
<tr>
<th></th>
<th>Size</th>
<th>Age</th>
<th>License</th>
<th>Fight Time—SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>Min</td>
<td>Max</td>
<td>M</td>
</tr>
<tr>
<td>Group 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=13</td>
<td>22</td>
<td>20</td>
<td>27</td>
<td>12</td>
</tr>
<tr>
<td>Group 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=13</td>
<td>22</td>
<td>20</td>
<td>29</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>N=26</td>
<td>22</td>
<td>20-29</td>
<td>26*</td>
</tr>
</tbody>
</table>

*Two participants were within three flight lessons of completing their commercial certificates with instrument and multi-engine ratings when the experiment began but completed their certificate/ratings before starting their training for the experiment.

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 $F = 1.010, p = .324$. Similarly, there was no significant difference in the
participant’s ability to complete pilot training and in higher order thinking awareness between the groups, \( F = 0.915, p = 0.348 \) and \( F = 0.572, p = 0.457 \), respectively. Table 3 shows the means and standard deviations of these three measurements.

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

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vocabulary</td>
<td>48.661</td>
<td>1</td>
<td>48.661</td>
<td>1.010</td>
<td>.324</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1204.005</td>
<td>25</td>
<td>48.160</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>145.200</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>16.962</td>
<td>1</td>
<td>16.962</td>
<td>0.915</td>
<td>.348</td>
</tr>
<tr>
<td>Within Groups</td>
<td>444.923</td>
<td>24</td>
<td>18.528</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>461.885</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HOT Awareness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>.127</td>
<td>1</td>
<td>.127</td>
<td>0.572</td>
<td>.457</td>
</tr>
<tr>
<td>Within Groups</td>
<td>5.317</td>
<td>24</td>
<td>.222</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5.444</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Vocabulary</th>
<th>Rotations</th>
<th>HOTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>Group 1</td>
<td>49.62 (6.87)</td>
<td>12.75 (4.20)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>46.93 (7.00)</td>
<td>14.57 (4.40)</td>
</tr>
</tbody>
</table>

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

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 treatment. 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, metacognitive awareness, and piloting skills.

Table 4. Pretest Statistical Significance of Pilot Performance

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Correct Clearance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>2.806E-05</td>
<td>1</td>
<td>2.806E-05</td>
<td>0.003</td>
<td>.960</td>
</tr>
<tr>
<td>Within Groups</td>
<td>0.175</td>
<td>16</td>
<td>1.092E-02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Correct Non-clearance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>4.477-04</td>
<td>1</td>
<td>4.777-04</td>
<td>.037</td>
<td>.849</td>
</tr>
<tr>
<td>Within Groups</td>
<td>0.192</td>
<td>16</td>
<td>1.197E-02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedural Errors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>0.136</td>
<td>1</td>
<td>0.136</td>
<td>0.291</td>
<td>.597</td>
</tr>
<tr>
<td>Within Groups</td>
<td>7.475</td>
<td>16</td>
<td>0.467</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heading Deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>2.206E-03</td>
<td>1</td>
<td>2.206E-03</td>
<td>0.000</td>
<td>.995</td>
</tr>
<tr>
<td>Within Groups</td>
<td>748.211</td>
<td>16</td>
<td>46.763</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altitude Deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>3707.814</td>
<td>1</td>
<td>3707.814</td>
<td>0.288</td>
<td>.599</td>
</tr>
<tr>
<td>Within Groups</td>
<td>205927.542</td>
<td>16</td>
<td>12870.471</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airspeed Deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>103.759</td>
<td>1</td>
<td>103.759</td>
<td>0.916</td>
<td>.353</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1811.475</td>
<td>16</td>
<td>113.217</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The final step, in determining if any preexisting differences were present, was an analysis of the pretest differences between groups on the independent variables within each dependent variable. The dependent variables were pilot performance, situational awareness, and aeronautical decision-making. This was accomplished by administering a pretest and analyzing the independent variables related to each dependent variable. Again, ANOVA were used to make
these determinations and the results of analyses are shown in Table 4 (pilot performance), Table 7 (situational awareness), and Table 11 (aeronautical decision-making). Table 4 shows the statistical significance of the pilot performance measurements.

Tables 5 and 6 show the means and standard deviations of the pilot performance measurements and for heading, altitude, and airspeed deviations. None of the pilot performance measurements showed a significant difference between groups on the pretest.

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

<table>
<thead>
<tr>
<th></th>
<th>% Correct Clearance</th>
<th>% Correct Non-Clearance</th>
<th>Procedural Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>Group 1</td>
<td>0.827 (0.109)</td>
<td>0.758 (0.116)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>0.825 (9.790E-02)</td>
<td>0.748 (0.101)</td>
</tr>
</tbody>
</table>

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

Table 6. Mean and Standard Deviations of the Heading, Altitude, and Airspeed Deviation

<table>
<thead>
<tr>
<th></th>
<th>Heading</th>
<th>Altitude</th>
<th>Airspeed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>Group 1</td>
<td>11.637 (6.479)</td>
<td>56.313 (28.653)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>10.699 (7.067)</td>
<td>84.989 (157.872)</td>
</tr>
</tbody>
</table>

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

Table 7 shows the statistical significance of each of the situational awareness independent variables. None of the situational awareness measurements showed a significant difference between groups on the pretest either. Tables 8 and 9 show the means and standard deviations for the radio communications measures and for judgment and noticed indicators used in measuring situational awareness. The measurements indicating situational awareness were correct radio
calls in clearances and outside of the clearance, correct judgments, and events noticed, unnoticed, and percentage noticed.

Table 7. Pretest Statistical Significance of Situational Awareness

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct Clearance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>0.469</td>
<td>1</td>
<td>0.469</td>
<td>0.032</td>
<td>.861</td>
</tr>
<tr>
<td>Within Groups</td>
<td>236.475</td>
<td>16</td>
<td>14.780</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct Non-clearance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>1.111</td>
<td>1</td>
<td>1.111</td>
<td>0.294</td>
<td>.595</td>
</tr>
<tr>
<td>Within Groups</td>
<td>60.500</td>
<td>16</td>
<td>3.781</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct Judgments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>2.500E-02</td>
<td>1</td>
<td>2.500E-02</td>
<td>0.008</td>
<td>.930</td>
</tr>
<tr>
<td>Within Groups</td>
<td>49.975</td>
<td>16</td>
<td>3.123</td>
<td></td>
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</tr>
<tr>
<td>Noticed</td>
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</tr>
<tr>
<td>Between Groups</td>
<td>0.000</td>
<td>1</td>
<td>0.000</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>8.500</td>
<td>16</td>
<td>0.531</td>
<td></td>
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<tr>
<td>Unnoticed</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>0.225</td>
<td>1</td>
<td>0.225</td>
<td>0.293</td>
<td>.596</td>
</tr>
<tr>
<td>Within Groups</td>
<td>12.275</td>
<td>16</td>
<td>0.767</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Noticed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>4.444E-02</td>
<td>1</td>
<td>4.444E-02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within Groups</td>
<td>1.678</td>
<td>16</td>
<td>0.105</td>
<td>0.424</td>
<td>.524</td>
</tr>
</tbody>
</table>

Table 8. Mean and Standard Deviations of Correct Clearances, Non-Clearances, and Judgments

<table>
<thead>
<tr>
<th></th>
<th>Correct Clearance</th>
<th>Correct Non-Clearance</th>
<th>Correct Judgments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest Group 1</td>
<td>19.20 (4.34)</td>
<td>11.50 (2.27)</td>
<td>2.70 (1.95)</td>
</tr>
<tr>
<td>Group 2</td>
<td>18.88 (3.09)</td>
<td>11.00 (1.41)</td>
<td>2.63 (1.51)</td>
</tr>
</tbody>
</table>

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

Table 9. Mean and Standard Deviations of Events Noticed, Unnoticed, and Percent Noticed

<table>
<thead>
<tr>
<th></th>
<th>Noticed</th>
<th>Unnoticed</th>
<th>% Noticed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest Group 1</td>
<td>0.50 (0.71)</td>
<td>1.40 (0.97)</td>
<td>0.267 (0.370)</td>
</tr>
<tr>
<td>Group 2</td>
<td>0.50 (0.76)</td>
<td>1.63 (0.74)</td>
<td>0.167 (0.252)</td>
</tr>
</tbody>
</table>

Note: Values shown in parentheses are standard deviations while all other values are the means of the variable.
The independent variables used to measure aeronautical decision-making include in clearance mistakes, out of clearance mistakes, incorrect judgments, percentage of correct judgments, and percentage of correct procedures. Table 10 shows the mean and standard deviations of these independent measurements. None of these measurements showed a significant difference between groups on the pretest for aeronautical decision-making (see Table 11).

Table 10. Mean and Standard Deviations of Aeronautical Decision-Making Independent Measurements

<table>
<thead>
<tr>
<th></th>
<th>Incorrect Clearances</th>
<th>Incorrect Non-clearances</th>
<th>Incorrect Judgments</th>
<th>% Correct Judgments</th>
<th>% Procedural Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>Group 1</td>
<td>Group 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.90 (2.13)</td>
<td>4.00 (2.14)</td>
<td>3.60 (1.65)</td>
<td>4.50 (3.06)</td>
<td>0.410 (0.211)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.75 (1.58)</td>
<td>4.75 (3.11)</td>
<td>0.408 (0.202)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.20 (0.63)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.38 (0.74)</td>
</tr>
</tbody>
</table>

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

Table 11. Pretest Statistical Significance of Aeronautical Decision-Making

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>$df$</th>
<th>Mean Square</th>
<th>$F$</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect Clearance</td>
<td>Between Groups</td>
<td>4.444E-02</td>
<td>1</td>
<td>4.444E-02</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>72.900</td>
<td>16</td>
<td>4.556</td>
<td></td>
</tr>
<tr>
<td>Incorrect Non-clearance</td>
<td>Between Groups</td>
<td>1.000E-01</td>
<td>1</td>
<td>1.000E-01</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>41.900</td>
<td>16</td>
<td>2.619</td>
<td></td>
</tr>
<tr>
<td>Incorrect Judgments</td>
<td>Between Groups</td>
<td>0.278</td>
<td>1</td>
<td>0.278</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>152.000</td>
<td>16</td>
<td>9.500</td>
<td></td>
</tr>
<tr>
<td>% Correct Judgments</td>
<td>Between Groups</td>
<td>1.235E-05</td>
<td>1</td>
<td>1.235E-05</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>0.686</td>
<td>16</td>
<td>4.289E-02</td>
<td></td>
</tr>
<tr>
<td>% Procedural Errors</td>
<td>Between Groups</td>
<td>0.136</td>
<td>1</td>
<td>0.136</td>
<td>0.291</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>7.475</td>
<td>16</td>
<td>0.467</td>
<td></td>
</tr>
</tbody>
</table>
Tables 1, 2, 4, 7, and 11 showed that there were no significant differences between the groups on any of the independent 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.

Dependent variables

Analyses of several posttest independent variables were made to determine the effect of the intervention on the dependent variable (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 12, 15, 18, and 20).

Pilot Performance Data

Pilot performance was assessed in a similar manner to that which is used by the Federal Aviation Administration (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 training device (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 radio communications accuracy.

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 for the same activity between participants, accumulative scores were unusable. The three deviation scores were recorded by the training device (ATD), calculated in Excel, and analyzed in SPSS.

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 12 shows the analysis of these observations. The ANOVA only showed significant differences between the groups for the percentage of correct non-clearance radio calls but not for the other average deviations and measurements. The percentage of correct out of clearance activities was $F = 13.176, p = .002$ (see Table 12). The means and standard deviations for these measurements of pilot performance are found in Tables 13 and 14. Additional, analysis of these measurements is necessary to test the effect of the treatment between the pre- and posttest.
Table 12. Posttest Statistical Significance of Pilot Performance

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Within Groups</td>
<td>9.960E-02</td>
<td>16</td>
<td>6.225E-02</td>
<td></td>
</tr>
<tr>
<td>% Correct Non-clearance</td>
<td>Between Groups</td>
<td>1.633E-02</td>
<td>1</td>
<td>1.633E-03</td>
<td>0.098</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>0.268</td>
<td>16</td>
<td>1.672E-02</td>
<td></td>
</tr>
<tr>
<td>Procedural Errors</td>
<td>Between Groups</td>
<td>3.361E-03</td>
<td>1</td>
<td>3.361E-03</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>12.114</td>
<td>15</td>
<td>0.808</td>
<td></td>
</tr>
<tr>
<td>Heading Deviation</td>
<td>Between Groups</td>
<td>1.961</td>
<td>1</td>
<td>1.961</td>
<td>0.169</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>185.299</td>
<td>16</td>
<td>11.581</td>
<td></td>
</tr>
<tr>
<td>Altitude Deviation</td>
<td>Between Groups</td>
<td>4707.107</td>
<td>1</td>
<td>4707.107</td>
<td>0.226</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>332974.211</td>
<td>16</td>
<td>20810.888</td>
<td></td>
</tr>
<tr>
<td>Airspeed Deviation</td>
<td>Between Groups</td>
<td>6.369</td>
<td>1</td>
<td>6.369</td>
<td>0.445</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>228.864</td>
<td>16</td>
<td>14.304</td>
<td></td>
</tr>
</tbody>
</table>

Table 13. Mean and Standard Deviations of the Pretest/Posttest Pilot Performance Measurements

<table>
<thead>
<tr>
<th></th>
<th>% Correct Clearance</th>
<th>% Non-Clearance</th>
<th>Procedural Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>Group 1</td>
<td>0.827 (0.109)</td>
<td>0.758 (0.116)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>0.825 (9.790E-02)</td>
<td>0.748 (0.101)</td>
</tr>
<tr>
<td>Posttest</td>
<td>Group 1</td>
<td>0.845 (8.167E-02)</td>
<td>0.770 (9.429E-02)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>0.710 (7.59E-02)</td>
<td>0.789 (0.164)</td>
</tr>
<tr>
<td>Difference</td>
<td>Group 1</td>
<td>0.20 (0.63)</td>
<td>0.20 (0.42)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>0.38 (0.74)</td>
<td>0.00 (1.07)</td>
</tr>
</tbody>
</table>

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

The effect of the treatment between the pre- and posttest results was analyzed. This comparison subtracted the pretest from the posttest performance measurements to determine the change that had occurred between the tests because of the treatments. ANOVA calculations were conducted on all the performance measurements. The results indicated that there was a
significant difference between the two groups on the change in percentage of correct in clearance radio responses, $F = 5.532 p = .032$ (see Table 15).

Table 14. Mean and Standard Deviations of the Pretest/Posttest Heading, Altitude, and Airspeed

<table>
<thead>
<tr>
<th></th>
<th>Heading</th>
<th>Altitude</th>
<th>Airspeed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pretest</strong></td>
<td>Group 1</td>
<td>11.637 (6.479)</td>
<td>56.313 (28.653)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>10.699 (7.067)</td>
<td>84.989 (157.872)</td>
</tr>
<tr>
<td><strong>Posttest</strong></td>
<td>Group 1</td>
<td>5.641 (4.234)</td>
<td>113.482 (160.867)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>6.31 (1.861)</td>
<td>89.048 (122.515)</td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td>Group 1</td>
<td>5.996 (5.654)</td>
<td>-57.169 (153.536)</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>4.069 (7.262)</td>
<td>-4.0583 (224.825)</td>
</tr>
</tbody>
</table>

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

Table 15. Posttest Statistical Significance of the Change ($\Delta$) in Pilot Performance

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta$ % Correct Clearance</td>
<td>Between Groups</td>
<td>790.103</td>
<td>1</td>
<td>790.103</td>
<td>5.532</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>2285.071</td>
<td>16</td>
<td>142.817</td>
<td></td>
</tr>
<tr>
<td>$\Delta$ % Non-clearance</td>
<td>Between Groups</td>
<td>703.447</td>
<td>1</td>
<td>703.447</td>
<td>3.798</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>2963.653</td>
<td>16</td>
<td>185.228</td>
<td></td>
</tr>
<tr>
<td>$\Delta$ Procedural Errors</td>
<td>Between Groups</td>
<td>0.173</td>
<td>1</td>
<td>0.178</td>
<td>0.296</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>9.600</td>
<td>16</td>
<td>0.600</td>
<td></td>
</tr>
<tr>
<td>$\Delta$ Heading Deviation</td>
<td>Between Groups</td>
<td>2.095</td>
<td>1</td>
<td>2.095</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>748.548</td>
<td>16</td>
<td>46.784</td>
<td></td>
</tr>
<tr>
<td>$\Delta$ Altitude Deviation</td>
<td>Between Groups</td>
<td>16770.297</td>
<td>1</td>
<td>16770.297</td>
<td>0.454</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>590626.352</td>
<td>16</td>
<td>36914.147</td>
<td></td>
</tr>
<tr>
<td>$\Delta$ Airspeed Deviation</td>
<td>Between Groups</td>
<td>58.714</td>
<td>1</td>
<td>58.714</td>
<td>0.496</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>1894.047</td>
<td>16</td>
<td>118.378</td>
<td></td>
</tr>
</tbody>
</table>
Table 15 also shows a number of performance indicators improved between the pre- and posttest but not significant at the $p < .05$ level. The means and standard deviations of these measurements are found in Tables 16 and 17. Several other performance indicators were analyzed and showed improvement but they were not significant and they were not reported in the tables.

Table 16. Mean and Standard Deviations of the Pre- and Posttest Change in Pilot Performance

<table>
<thead>
<tr>
<th></th>
<th>$\Delta$ % Correct Clearances</th>
<th>$\Delta$ % Correct Non-clearances</th>
<th>$\Delta$ Procedural Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>0.827 (0.109)</td>
<td>0.758 (0.116)</td>
<td>0.20 (0.63)</td>
</tr>
<tr>
<td>Group 2</td>
<td>0.825 (0.079)</td>
<td>0.748 (0.101)</td>
<td>0.38 (0.74)</td>
</tr>
<tr>
<td>Posttest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>0.845 (0.082)</td>
<td>0.770 (0.094)</td>
<td>0.40 (0.97)</td>
</tr>
<tr>
<td>Group 2</td>
<td>0.710 (0.075)</td>
<td>0.789 (0.164)</td>
<td>0.43 (0.79)</td>
</tr>
</tbody>
</table>

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

Table 17. Mean and Standard Deviations of the Pre- and Posttest Heading, Altitude, and Airspeed Deviation

<table>
<thead>
<tr>
<th></th>
<th>$\Delta$ Heading</th>
<th>$\Delta$ Altitude</th>
<th>$\Delta$ Airspeed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>11.637 (6.479)</td>
<td>56.313 (28.653)</td>
<td>20.776 (10.721)</td>
</tr>
<tr>
<td>Group 2</td>
<td>11.615 (7.179)</td>
<td>84.989 (157.872)</td>
<td>15.571 (10.464)</td>
</tr>
<tr>
<td>Posttest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>5.641 (4.234)</td>
<td>113.482 (160.867)</td>
<td>14.095 (4.285)</td>
</tr>
<tr>
<td>Group 2</td>
<td>6.31 (2.287)</td>
<td>89.048 (122.515)</td>
<td>12.582 (3.318)</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>5.996 (5.654)</td>
<td>-57.169 (153.536)</td>
<td>6.681 (11.856)</td>
</tr>
<tr>
<td>Group 2</td>
<td>4.069 (7.262)</td>
<td>-4.0583 (224.825)</td>
<td>2.990 (9.778)</td>
</tr>
</tbody>
</table>

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

Situational Awareness Data

Situational awareness was measured by counting the number of correct in clearance and out of clearance responses, correct judgments, and events noticed and by assessing the
Development and Transfer of Higher order Thinking

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. Only one of these indicators showed a significant difference on the posttest. Table 18 shows a significant improvement in the number of incorrect non-clearance responses; that is, \( F = 9.488, p = .007 \). Table 18 also showed there were no significant differences found in the remaining counts and questions measured, and there were no significant differences on the change occurring between the pre-and posttest. Table 19 shows the means and standard deviations of the measures of situational awareness.

Table 18. Posttest Statistical Significance of Situational Awareness

<table>
<thead>
<tr>
<th>Measure</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct Clearance</td>
<td>Between Groups</td>
<td>22.003</td>
<td>1</td>
<td>22.003</td>
<td>3.5682</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>98.275</td>
<td>16</td>
<td>6.142</td>
<td></td>
</tr>
<tr>
<td>Incorrect Clearance</td>
<td>Between Groups</td>
<td>50.625</td>
<td>1</td>
<td>50.625</td>
<td>9.488</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>85.375</td>
<td>16</td>
<td>5.336</td>
<td></td>
</tr>
<tr>
<td>Correct Judgments</td>
<td>Between Groups</td>
<td>10.000</td>
<td>1</td>
<td>10.000</td>
<td>1.808</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>88.500</td>
<td>16</td>
<td>5.531</td>
<td></td>
</tr>
<tr>
<td>Δ Correct Judgments</td>
<td>Between Groups</td>
<td>9.025</td>
<td>1</td>
<td>9.025</td>
<td>0.754</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>191.475</td>
<td>16</td>
<td>11.967</td>
<td></td>
</tr>
<tr>
<td>Δ % Noticed</td>
<td>Between Groups</td>
<td>521.605</td>
<td>1</td>
<td>521.605</td>
<td>0.126</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>66083.333</td>
<td>16</td>
<td>4130.208</td>
<td></td>
</tr>
</tbody>
</table>

Aeronautical decision-making Data

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.

Table 19. Mean and Standard Deviations Pre- and Posttest Measurements of Situational Awareness

<table>
<thead>
<tr>
<th></th>
<th>Correct Clearance</th>
<th>Incorrect Clearance</th>
<th>Correct Judgments</th>
<th>Δ Correct Judgments</th>
<th>Δ % Noticed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest Group 1</td>
<td>19.20 (4.34)</td>
<td>11.50 (2.27)</td>
<td>2.70 (1.95)</td>
<td>2.70 (1.95)</td>
<td>0.267 (0.370)</td>
</tr>
<tr>
<td>Pretest Group 2</td>
<td>18.88 (3.09)</td>
<td>11.00 (1.41)</td>
<td>2.63 (1.51)</td>
<td>2.63 (1.51)</td>
<td>0.167 (0.252)</td>
</tr>
<tr>
<td>Posttest Group 1</td>
<td>18.60 (2.76)</td>
<td>13.10 (1.73)</td>
<td>3.50 (2.92)</td>
<td>3.50 (2.92)</td>
<td>0.367 (0.483)</td>
</tr>
<tr>
<td>Posttest Group 2</td>
<td>16.38 (2.07)</td>
<td>13.15 (2.78)</td>
<td>2.00 (1.31)</td>
<td>2.00 (1.31)</td>
<td>0.375 (0.518)</td>
</tr>
<tr>
<td>Difference Group 1</td>
<td>-0.60 (5.85)</td>
<td>7.10 (3.73)</td>
<td>0.80 (4.10)</td>
<td>0.80 (4.10)</td>
<td></td>
</tr>
<tr>
<td>Difference Group 2</td>
<td>-2.50 (4.47)</td>
<td>5.38 (2.07)</td>
<td>-0.63 (2.39)</td>
<td>-0.63 (2.39)</td>
<td></td>
</tr>
</tbody>
</table>

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

Table 20. Posttest Statistical Significance of Aeronautical Decision-Making

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect Non-clearance</td>
<td>Between Groups</td>
<td>0.336</td>
<td>1</td>
<td>0.336</td>
<td>.068</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>78.775</td>
<td>16</td>
<td>4.923</td>
<td></td>
</tr>
<tr>
<td>% Correct Judgments</td>
<td>Between Groups</td>
<td>0.116</td>
<td>1</td>
<td>0.116</td>
<td>4.157</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>0.447</td>
<td>16</td>
<td>2.794E-02</td>
<td></td>
</tr>
<tr>
<td>Δ Incorrect Clearance</td>
<td>Between Groups</td>
<td>47.669</td>
<td>1</td>
<td>47.669</td>
<td>4.671</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>163.275</td>
<td>16</td>
<td>10.205</td>
<td></td>
</tr>
<tr>
<td>Δ Incorrect Non-clearance</td>
<td>Between Groups</td>
<td>46.225</td>
<td>1</td>
<td>46.225</td>
<td>4.748</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>155.775</td>
<td>16</td>
<td>9.736</td>
<td></td>
</tr>
<tr>
<td>Δ % Correct Judgment</td>
<td>Between Groups</td>
<td>1137.778</td>
<td>1</td>
<td>1137.778</td>
<td>2.798</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>6506.667</td>
<td>16</td>
<td>406.667</td>
<td></td>
</tr>
<tr>
<td>HOT Awareness</td>
<td>Between Groups</td>
<td>0.840</td>
<td>1</td>
<td>0.840</td>
<td>5.399</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>2.179</td>
<td>14</td>
<td>0.156</td>
<td></td>
</tr>
</tbody>
</table>
Table 20 shows the results of ANOVA on the changes incorrect clearance and non-clearance responses, and on the higher order thinking awareness survey, $F = 4.671$, $p = .046$, $F = 4.748$, $p = .045$, and $F = 5.399$, $p = .036$, respectively. Tables 21 and 22 show the means and standard deviations of the aeronautical decision-making measures.

Table 21. Mean and Standard Deviations of Pre- and Posttest Judgment, Noticed, and Procedure Deviation

<table>
<thead>
<tr>
<th></th>
<th>Judgment Correct</th>
<th>Judgment Incorrect</th>
<th>% Judgment Correct</th>
<th>Noticed</th>
<th>Unnoticed</th>
<th>% Noticed</th>
<th>Procedural Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
<td>Group 2</td>
<td>Group 1</td>
<td>Group 2</td>
<td>Group 1</td>
<td>Group 2</td>
<td>Group 1</td>
</tr>
<tr>
<td>Pretest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>2.70 (1.95)</td>
<td>2.63 (1.51)</td>
<td>4.50 (3.06)</td>
<td>4.75 (3.11)</td>
<td>0.410 (0.211)</td>
<td>0.048 (0.202)</td>
<td>0.50 (0.71)</td>
</tr>
<tr>
<td>Group 2</td>
<td>2.30 (1.16)</td>
<td>2.00 (1.31)</td>
<td>2.30 (3.16)</td>
<td>3.63 (2.62)</td>
<td>0.537 (0.190)</td>
<td>0.375 (0.133)</td>
<td>1.10 (1.45)</td>
</tr>
<tr>
<td>Posttest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>0.80 (4.10)</td>
<td>0.63 (2.39)</td>
<td>2.20 (3.71)</td>
<td>1.13 (5.54)</td>
<td>0.60 (1.184)</td>
<td>0.38 (1.77)</td>
<td>0.70 (0.95)</td>
</tr>
<tr>
<td>Group 2</td>
<td>0.70 (0.48)</td>
<td>0.375 (1.77)</td>
<td>0.70 (0.95)</td>
<td>0.75 (1.28)</td>
<td>0.70 (0.95)</td>
<td>0.375 (1.77)</td>
<td>0.70 (0.95)</td>
</tr>
<tr>
<td>Difference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>0.80 (4.10)</td>
<td>0.63 (2.39)</td>
<td>2.20 (3.71)</td>
<td>1.13 (5.54)</td>
<td>0.60 (1.184)</td>
<td>0.38 (1.77)</td>
<td>0.70 (0.95)</td>
</tr>
<tr>
<td>Group 2</td>
<td>0.70 (0.48)</td>
<td>0.375 (1.77)</td>
<td>0.70 (0.95)</td>
<td>0.75 (1.28)</td>
<td>0.70 (0.95)</td>
<td>0.375 (1.77)</td>
<td>0.70 (0.95)</td>
</tr>
</tbody>
</table>

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

Table 22. Mean and Standard Deviations of the Pre- and Posttest Higher Order Thinking Awareness Measurements

<table>
<thead>
<tr>
<th></th>
<th>HOTA</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
<td>Group 2</td>
</tr>
<tr>
<td>Pretest</td>
<td>5.345 (0.548)</td>
<td>5.220 (0.367)</td>
</tr>
<tr>
<td>Posttest</td>
<td>5.634 (0.354)</td>
<td>5.213 (0.428)</td>
</tr>
<tr>
<td>Difference</td>
<td>0.280 (0.457)</td>
<td>0.198 (0.473)</td>
</tr>
</tbody>
</table>

*Note.* Values shown in parentheses are standard deviations while all other values are the means of the variable.
CHAPTER 5: RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Summary and Discussion of Results

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 and pilot performance compared to non-problem based instruction?

Discussion of Pretest Analysis

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.
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 Federal Aviation Administration (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.

Discussion of Posttest Analysis

The posttest analysis also included a pilot performance test and a written evaluation. Table 23 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 23. Posttest Measurements of the Dependent Variables

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Measurements</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot Performance</td>
<td>% Correct Clearance</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>% Correct Non-clearance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Procedural Errors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heading Deviation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Altitude Deviation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Airspeed Deviation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Δ % Correct Clearance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Δ % Correct Non-clearance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Δ Procedural Errors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Δ Heading Deviation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Δ Altitude Deviation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Δ Airspeed Deviation</td>
<td></td>
</tr>
<tr>
<td>Situational Awareness</td>
<td>Correct Clearance</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Incorrect Clearance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Correct Judgment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Δ Correct Judgment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Δ % Noticed</td>
<td></td>
</tr>
<tr>
<td>Aeronautical Decision-Making</td>
<td>Incorrect Non-clearance</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>% Correct Judgments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Δ Incorrect Clearance</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Δ Incorrect Non-clearance</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>Δ Correct Judgments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HOTA</td>
<td>*</td>
</tr>
</tbody>
</table>

Note. The statistical significance is < .05.

The intervention produced significant improvements and did not produce any adverse effects on pilot performance evaluation and written test (see Table 23). That is, the treatment group (problem-based learning) did better on all pilot performance, situational awareness, and aeronautical decision-making measurements, and significantly better on one pilot performance and situational awareness, and on three of the aeronautical decision-making measurements (see Table 23). Significant improvements in pilot performance were found in the percentage of correct radio call responses to flight clearances. Table 23 also shows that significant improvements were found in situational awareness (number of correct clearances) and
aeronautical decision-making (change in incorrect clearances, change in incorrect outside the clearance, and higher order thinking awareness). Again, 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.

Table 23 also shows significant improvement on the written evaluation, higher order thinking awareness test. 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 significantly better than the non-PBL group.

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 number of correct non-clearance radio calls. This indicates that the participants were more aware of their position or situation than the maneuvers-based group. Likewise, the number of incorrect non-clearance radio calls showed reduction. This indicated fewer bad judgments or errors. Finally, the awareness of higher order thinking improved in the treatment group (PBL). This is an important finding because it indicates that the participants are
now more aware of critical thinking, evaluation, and judgment skills. This finding will be
discussed more fully in the next section.

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.

Limitations of the Study

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
Development and Transfer of Higher order Thinking

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.

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.

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.

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.

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.
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.

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.

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 or more of the independent variables within each dependent variable (pilot performance, situational awareness, and aeronautical decision-making). Additionally, all independent variables measured showed improvement although they were not significant at the .05 alpha level.
Conclusions

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.

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 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 show significances at the .05 alpha level.

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.

Recommendations

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.
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.
The methods and strategies for teaching HOTS are being adopted rapidly throughout the aviation training community including providers of non-TAA flight training. These non-TAA training providers include the Aero-Tech (Lexington, KY), Aviation Supplies & Academics, Inc. (Newcastle, WA), CAP Aviation Consulting Group, L.L.C. (Daytona Beach, FL), Embry Riddle Aeronautical University, Middle Tennessee State University, and University of North Dakota. 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.

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.
REFERENCES


Anchored Instruction Theory (n.d.) Retrieved August 26, 2003, from http://www.personal.psu.edu/users/y/z/yzy100/KNOWLEDGE_BASE/content/7-anchor.htm


Accepted Instructor Syllabus v1.0.pdf


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 joint 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.)

<table>
<thead>
<tr>
<th>Subject</th>
<th>YES</th>
<th>NO</th>
<th>WRONG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sets proper squawk code (0427)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dials in Ground Control Frequency (121.8 or 121.9)</td>
<td>YES</td>
<td>NO</td>
<td>WRONG</td>
</tr>
<tr>
<td>Calls for taxi instructions</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>

**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)

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

**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**

<table>
<thead>
<tr>
<th>Subject</th>
<th>YES</th>
<th>NO</th>
<th>WRONG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contacts Tower</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dials in Tower Frequency (123.95)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sets departure frequency in radio #2 or stand-by radio (124.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calls ready for takeoff</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>

**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
  (110-120 SR22, 105 Mooney) (SR22 request subject state climb speed) (±10 knots)
- Flies RWY Heading (120° ± 10°)

**Controller:** TOWER
November 328
Contact Departure 124.7

**Subject** - Subject repeats frequency
YES NO

**Subject** - Selects Departure Frequency (124.7)
- Contacts Departure
  (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’)
- Reports level at 3000’

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

Subject - Repeats clearance
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

Controller: Radio Chatter
- Ignore

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

Controller: DEPARTURE

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

<table>
<thead>
<tr>
<th>Subject - repeats holding clearance (7)</th>
<th>YES</th>
<th>SKIP</th>
<th>WRONG</th>
<th>REPEAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hold Northwest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Of Farmington 339 Radial at 6 DME</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On the Farmington 339° Radial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintain 3000’</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expect one turn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report established</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Controller: Radio Chatter

Subject - Reports entering holding inbound

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

Subject - Responds

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
Climbing 6 DME
Climb and maintain 4000’
Controller: Radio Chatter

Subject - Departs Holding and tracks inbound
- 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 320°
Maintain 5000’

**Subject** - Repeats clearance (7) YES SKIP WRONG REPEAT

| Vector to localizer (RWY 9R) | __ | __ | ___ | ___ |
| Right turn heading 320° | __ | __ | ___ | ___ |
| Maintain 5000’ | __ | __ | ___ | ___ |

**Subject** – YES NO WRONG NA

- Turns right heading 320 (± 10°) __ __ ___ ___
- 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 –  
- Repeats frequency change  YES NO WRONG  
- Dials in correct frequency (125.0)  YES NO WRONG  
- Calls Approach  YES NO

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 (320° heading), provide the following clearance.

Nov 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.
- Makes left 360

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’)*

Nov 328
Turn Right 060° *(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 060°
- 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**

Nov 328
What will you final approach airspeed be?

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

Controller: **TOWER**

Nov 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 opPorturey: 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
SCENARIO 2

SUBJECT______________________________________________________________

DATE______________________________________________________________________________

TIME OF SCENARIO______________________________________________________________________

ORDER OF SCENARIO ON THIS DAY FIRST SECOND

RESEARCH ASSISTANTS CONDUCTING SCENARIO:

Experimenter - ___________________________________________________________________

Controller - _____________________________________________________________________

Other - _______________________________________________________________________

_________________________________________________________________________________

LEG 1

SCENARIO: 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

Weather Information from ATIS (124.9)
1400 Zulu Observation
Wind Calm
Ceiling 800 Overcast (1706 MSL)
Visibility 5 miles Fog
Temperature -5 (23°F)
Dewpoint -7 (20°F)
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

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)  
____ Cleared to St. Paul Downtown as filed  
____ Climb and maintain 6000  
____ Contact Departure on 125.0  
____ Squawk 2345

Subject – 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 –  
- 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)  
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)  
____ Left Turn  
____ Direct Farmington  
____ Climb and maintain 5000’

Subject – Proceeds direct Farmington  
- Levels at 5000’ (± 100’)

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:
N328 roger, after Farmington cleared to LDASH
Via Victor 26
Report established on Victor 26

YES  NO  SKIP  WRONG  REPEAT

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)
Minneapolis Approach
121.2

YES  SKIP  WRONG  REPEAT

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 _______
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)  

<table>
<thead>
<tr>
<th>YES</th>
<th>SKIP</th>
<th>WRONG</th>
<th>REPEAT</th>
</tr>
</thead>
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<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>WRONG</th>
</tr>
</thead>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Subject - turns left
- maintains altitude w/in 100 ft
- Rolls out of turn on Victor 26 (071º)

**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.  

<table>
<thead>
<tr>
<th>RIGHT</th>
<th>WRONG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

**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**  *

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  

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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  
YES NO WRONG
(Teardrop or Direct)
- Sets up inbound course on OBS (251°)  
YES NO WRONG
- Reports entering holding

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 JULIET

**Subject** - Repeats clearance (7)  
___ 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 JULIET

**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)  
_____050º  
_____3000’

**Subject** -  
- Selects proper frequency (111.5)  
- Identifies proper freq.  
- Selects appropriate nav modes  
- levels off at 3000’ (±100’)  

**Controller**: Radio Chatter  
- Ignores

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

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

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

**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)

- Turn left
- 290°
- Descend and Maintain 2500’
- Intercept localizer for ILS RWY 32
- Report established (inbound)

**Subject** - Sets up inbound course on OBS (323°)
- reports established

**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)

- 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) outside 6.6) YES NO LATE (less than 6.0

Controller: TOWER

Subject - St Paul Tower 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

Controller: Radio Chatter

Controller: TOWER
November 328
Cleared to land RWY 32

Subject - Repeats clearance to land
- Fly the ILS approach within ½ scale deflection (glideslope and localizer)
- Maintains airspeed within 10 knots (100 knots)
- Lands aircraft safely

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

END OF PRACTICE SCENARIO