12-9-1992

Utilizing Instructional Design Constructs To Enhance Computer-Based Instruction in Air Traffic Controller Training

Theodore Scott Rhoads
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UTILIZING INSTRUCTIONAL DESIGN CONSTRUCTS
TO ENHANCE COMPUTER-BASED INSTRUCTION
IN AIR TRAFFIC CONTROLLER TRAINING

by

Theodore S. Rhoads

A Thesis Submitted to the
Office of Graduate Programs
in Partial Fulfillment of the Requirements for the Degree of
Master of Aeronautical Science

Embry-Riddle Aeronautical University
Daytona Beach, Florida
December 9, 1992
UTILIZING INSTRUCTIONAL DESIGN CONSTRUCTS
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Theodore Scott Rhoads

This thesis was prepared under the direction of the candidate's thesis committee chairman, Dr. Diana Carl, Department of Aeronautical Science, and has been approved by the members of his thesis committee. It was submitted to the Office of Graduate Programs and was accepted in partial fulfillment of the requirements for the degree of Master of Aeronautical Science.

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ABSTRACT

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Title: Utilizing Instructional Design Constructs To Enhance Computer-Based Instruction In Air Traffic Controller Training

Institution: Embry-Riddle Aeronautical University

Degree: Master of Aeronautical Science

Year: 1992

This study demonstrates that a computer-based instructional design format is appropriate for novice air traffic control (ATC) training. The computer presents the student with small amounts of information in tutorial and drill and practice sequences that necessitate student interactivity. The student is then periodically audit tested to ascertain mastery of the subject matter. The result of these mid-lesson evaluations serve as a self-check so that the student can assess his/her progress in the learning cycle. The systematic design of instruction and interactive approach to learning, enhances student motivation, improves learning and retention, while placing the responsibility of achieving specific learning objectives on the student. This study serves as a precursor to generating a broader field of computer-based ATC instruction.
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Introduction

Every user of the air traffic control system requires and deserves the optimum service that can be provided. One might assume that only the most qualified individuals are selected as Air Traffic Control Specialists (ATCS), however, recent research suggests that the selection and training of controllers is nugatory.

The current air traffic control work force is selected through a two stage selection system. The first stage consists of a paper-and-pencil test battery administered by the Office of Personnel Management (OPM). The OPM test requires that the hopeful trainee exhibit some of the fundamental decision making characteristics of an ATCS. The second stage of the selection process consists of condensed training and testing regimes in a nonradar environment (Rocco, Manning, & Wing, 1991).

Many deserving applicants, however, fail to score highly enough on the primary screening device (the OPM test) and as a result are not given the chance to succeed in air traffic control. By the same token, the skills of numerous applicants that score very highly on the OPM test are substandard; this is reflected by the 56% overall ATC training attrition rate (GAO, 1988a). The entire screening process appears to be based on selection criteria that may very well be ineffective in correctly identifying the individuals that exhibit the cognitive ability and spatial perception that is relevant in predicting success in air traffic control. This inadequate primary screening and subsequent ineffective training procedures may deny the flying public the most highly qualified ATC personnel.
Insufficient Work Force and Inadequate Training

Retirements, training attrition, and increased work loads are all contributing to this controller shortage. The Aviation Consumer Action Project stated that just to get back to 1980 benchmarks of full performance level personnel would take upwards of 3,000 controllers (Ott, 1992). It has been recently acknowledged that because of the full performance level controller shortages, the controllers and their supervisors were concerned about their ability to maintain system safety (GAO, 1987; GAO, 1989a).

In addition, many controllers felt that recent applicants were not receiving sufficient training prior to being certified on certain ATC positions (GAO, 1988b; GAO, 1989a). Air traffic field managers were also concerned about the poor quality of ATC training (GAO, 1989b). These air traffic field managers reported that some controllers were being trained to use air traffic procedures that were outdated and other entrant controllers received inadequate instruction from instructors that had not directed traffic for over two decades (GAO, 1990). Experts agreed that controller training must improve.

The zeitgeist for ATC training reform was fueled by deficiencies in the controller training program that proved to be life threatening. The National Transportation Safety Board directly linked deficiencies in controller training to contributing to loss of life in the 1987 midair collisions in Independence, Missouri and Orlando, Florida (GAO, 1990). In the Safety Board's judgment, improved training for controllers would have prevented these accidents. A potentially serious condition has developed; the safety of the nation's air traffic may be in the hands of an insufficient number of overworked and undertrained controllers.

A possible solution to the controller training and selection dilemma may be found in the ATC courses offered at the university level. In the university setting, the college student can learn about the ATC environment and decide by test scores and personal
interest whether he or she is motivated enough to continue with the training necessary to become a full performance level controller. Hilda Wing (1991), of the Staffing Policy Division of the FAA, noted that "the FAA presently has formal arrangements with a few collegiate programs in air traffic control, whose graduates will enter the FAA above the initial entry level" (p. 422). The university ATC courses offer a chance for students to experience the rigors of terminal, enroute, and non-radar ATC. This experience is accomplished via computer simulation models and on-the-job instruction/training in air traffic control practicum courses (Galotti, 1991).

Accordingly, it was proposed that a university ATC training option would lead to more accurate person/job matching, reduce attrition rates, and increase technical competence (University Aviation Association, 1990). However, studies indicate that the cadre of individuals that participate in the University Airway Science Curriculum, though more interested in an aviation-related career, have a greater attrition rate, and are not more technically competent than traditionally hired controllers (Broach, 1990; Broach, 1991; Clough, 1988).

Initially, it was felt that during regularly scheduled university coursework, students could be given the special talents needed in the field of ATC through knowledge and skill based testing, repeated computer simulation modules including computer-based instruction, and the ATC practicum. With this type of instructional process it was suggested that the student and instructor could accurately and methodically evaluate the individual's prospective air traffic control expertise and assess ATC competence before formally pursuing a career in air traffic control (Higher Education and Advanced Technology Staff, 1990; University Aviation Association, 1990). However, Broach (1991) suggested that there are no significant differences between traditional hired ATC personnel and the airway science trainees in-so-far-as the overall ATC training attrition
rate and technical competence was concerned. Nevertheless, it is still believed by some experts in the field, that a "completely effective training [program] would theoretically wipe out any individual differences in [ATC] performance" (Wing, 1991, p. 418).

In any case, it is clear that the present FAA training programs are not efficient, nor are they adequate (Smith, 1991). Therefore, several education and training institutions in the U.S. have been authorized by the FAA to spearhead innovative ATC training programs and develop effective curricula that will help supply qualified candidates to the depleted controller ranks. If the university ATC curriculum is to survive, instructional designers must escalate their efforts to effect a greater change in the efficiency and productivity of ATC instruction.

**Utilizing Instructional Design Precepts to Improve ATC Training**

Klein (1991) contends that "one of the most fundamental concepts in curriculum development is relevancy - the relationship to and importance of the curriculum to the lives of students" (p. 218). Klein confesses that as course relevancy declines, students become less involved in their learning and do not achieve the stated performance objectives of the curriculum. Because the ATC curriculum is entirely voluntary and extremely relevant to the student, this alone should provide important intrinsic motivational factors. In fact, it is this job relevancy that may be the primary reason university students choose the ATC courses. The students that are enrolled in university ATC programs can see the job potential in courses that teach actual ATC methods and procedures. Since the students are motivated to learn, then the deficiencies may rest entirely in the design of the instruction.

The purpose of any instruction "is to bring about a desired change in the learner's behaviour [sic]" (Davies, 1973, p. 90). The instructional design process can provide
necessary systematic guidelines to aid in ATC training and increase the benefits of ATC instruction. This stricture leads to creative, efficient, and effective instruction involving interactive educational experiences that may increase the appeal of the instruction (Hannafin & Peck, 1988).

Reigeluth (1983) contends that the result of instructional design (ID) is an architect's blueprint for what the instruction should be like. This author states that ID:

- is concerned with understanding, improving, and applying methods of instruction
- it is the process of deciding what methods of instruction are best for bringing about desired changes in student knowledge and skills for a specific course content and a specific student population. (p. 7)

Consequently, many theories have been advanced that attempt to explain how learning occurs, though it is not fully understood exactly how people learn or how the mind works. It is accepted, however, that when instructional design constructs are applied, they can aid in producing measurably better instruction. Instructional design is, by definition, a prescriptive science; "its primary purpose is to describe optimal methods of instruction" (Reigeluth, 1983, p. 21).

M. David Merrill (1971), agrees, confessing that teaching is not as mysterious an art as traditionally believed. Merrill suggests that teaching is something that can be planned and studied according to scientific principles and that the outcomes can be predicted if instruction proceeds in a systematic way. There are several principles that help guide instructional design and these are derived from behavioral psychology and cognitive psychology learning theory.

If behavioral psychology aids instructional design by explaining why behaviors occur, then its counterpart, cognitive psychology, attempts to determine how learning takes place and how best to improve it. When developing any pedagogy, greater
productivity and effectiveness of the instruction can be obtained from adhering to these well established learning principles of educational psychology. Adhering to learning theory precepts can have a great effect on how meaningful the instruction is, which in turn affects the strength of that learning (Hannafin & Peck, 1988).

Recognizing the importance of the instructional design process is only part of the solution toward building more effective ATC instruction. It is equally important that the most interactive information presentation method be identified, thereby increasing student participation and maximizing the learning experience. To refrain from using the most active media presentation forum would be pernicious.

The Computer: A Medium for Instruction

The computer has developed into an integral part of our society and has become an essential component of the modern university as well (Reeves, 1991). There is also a gradual but progressive movement in Europe and the U.S. to bring the computer into the mainstream of classroom instruction (Sugrue, 1991). However, all coursework is not suited for computerized instruction. Wilson (1991) offers some basic guidelines as to when and how computer-based instruction can be effectively utilized in the classroom. Reiser and Gagne (1983) also provide media selection models that determine the feasibility of using the computer. It is important to use the most appropriate media for each learning situation.

Computer-assisted instruction (CAI) is an educational medium by which instructional content is delivered by computer. By definition, employing the computer as a form of instruction, refers to "an interactive learning experience between a learner and a computer in which the computer provides the majority of the stimulus, the learner must respond, and the computer analyzes the response and provides feedback to the learner"
In accordance with this specialized format, CAI has a unique set of strengths that may be beneficially utilized in the ATC training realm.

There are many terms associated with computerized instruction and these terms have been used by various authors to refer to any of a set of interrelated concepts. Several authors use different terms to convey a variety of meanings. Gery (1987) provides an interesting table (figure 1) equating the various computer-based instructional nomenclature. Gery postulates that a valid synonym for CAI can be generated by selecting one term from each column and matching it with a term from the following column (Gery, 1987, p. 7).

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
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</thead>
<tbody>
<tr>
<td>Computer</td>
<td>Assisted</td>
<td>Instruction</td>
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<tr>
<td></td>
<td>Aided</td>
<td>Learning</td>
</tr>
<tr>
<td></td>
<td>Managed</td>
<td>Education</td>
</tr>
<tr>
<td></td>
<td>Based</td>
<td>Training</td>
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<tr>
<td></td>
<td>Enhanced</td>
<td>Teaching</td>
</tr>
<tr>
<td></td>
<td>Mediated</td>
<td>Development</td>
</tr>
<tr>
<td></td>
<td>Interactive</td>
<td>Study</td>
</tr>
</tbody>
</table>

Select one from each column

Figure 1. Computer-based Instructional Nomenclature

The expression that is used to describe the tutelage presented to any number of students by computer, will be referred in this research as computer-assisted instruction (CAI) or computer-based instruction (CBI). Though not all experts agree that the terms in figure 1 are synonymous, this researcher will equate the terms computer-assisted instruction, computer-aided instruction, and computer-based instruction.

Computers may not be especially well suited for every educational domain, but with the vast amount of human/machine interface inherent in the ATC field, instructional
software may be especially appropriate in this environment. In addition, educators and politicians have cogently argued for the use of computer-based programs as a means to help students develop the job skills necessary for the sophisticated tasks that are the reality of the technologically advanced world of the 21st century (Bok, 1986; Bonner, 1984).

By utilizing the computer as an instructional tool, one can reduce the amount of didactic tutelage, initiate active student responding, and the student can also benefit by progressing at his/her own pace (Bork, 1987; Hannafin & Peck, 1988; Shlechtet, 1991). There is little doubt that didactic pedagogic procedures in which learners are viewed as receptive repositories that eagerly await the deposits of experts, are not likely to result in effective, interesting, free-flowing, and interactive instruction (Brookfield, 1986). Rather than looking to concepts of instruction that draw on research from traditional teaching methods, it might be fruitful to consult concepts and practices that are drawn from recent research of computer-based instruction tempered with principles of instructional design.

Many students prefer, and appear to benefit from, teaching strategies that are individually oriented (Shlechter, 1991). Much of the recent research suggests that in some cases CAI can be a dynamic and stimulating resource that initiates student freedom in learning. Interactive CAI instruction can be more personalized and rest on the particular needs and progress of each student (Davies, 1973; Hannafin & Peck, 1988) (cf. Hativa, 1988; Suppes & Macken, 1978). Certain studies also suggest that when computer-based instruction is compared to other media that do not take into account individual differences, CAI produces more learning in a given amount of time or produces a given amount of learning in a shorter period of time (Bright, 1983; Gleason, 1981; Splittgerber, 1979).

In many cases, however, these studies are severely flawed. Some of these CAI studies "include disproportionate attrition from experimental groups, nonrandom assignment of students to treatments, [and] incommensurable instructional content
provided to control and treatment groups. In one review study, 26 out of 51 research reports were deemed unusable because of various methodological problems" (OTA, 1988, p. 47). Hannafin and Peck (1988) concur, pointing out that all CAI does not facilitate learning. These authors add that only well designed and highly interactive CAI is effective in boosting the learning curve.

A very appropriate mode of instruction for intellectual skill development is a medium that provides corrective, immediate, and precise feedback to the responses of the student during the learning process (Reiser & Gagne, 1983). Internalizing ATC rules, regulations, and procedures are very much a part of intellectual skill development. In the ATC classroom, the intellectual skill development areas include: concrete concepts, discrimination, defined concepts, rules, and problem solving. Gagne, Briggs, and Wager (1992) state that "an intellectual skill cannot be learned by simply being looked up or provided to the learner via verbal communication; it must be learned, recalled, and put into use at the proper time (p. 13). Therefore, it could be suggested that the interactive computer-based media could be appropriate in delivering specific, diagnostic feedback and aid in developing the intellectual skills required by the entrant ATC student. Accordingly, it may be of great value to the ATC instructional designer to develop a computer-based ATC paradigm that utilizes well established principles of cognitive learning theory.

The FAA has granted universities the opportunity to advance this sphere of training by investigating alternative modes of ATC education. Consequently, it is the purpose of this research to examine and describe how the instructional outcomes of the ATC learning environment can be optimized utilizing computer-based instruction.
Statement of the Problem

Present methods of ATC instruction by the federal government and by private universities usually conducted in a lecture or didactic format have experienced limited success. This study examines the effectiveness, efficiency, and appeal of CAI modules that utilize instructional design approaches in ATC knowledge and skill development. The CAI approach can be self-paced and provide corrective feedback to the learner during the learning process, however, it is unknown what effect this computerized instructional regime will have on ATC education and training in the university setting. This research, therefore, will compare and contrast the CAI and didactic modes of instruction in the ATC university environment.

The computer-based technique combines drill and practice, quizzes, as well as valuable tutorial sessions that are incorporated within the ATC instructional exercises. Identifying, interpreting, and generating terminal flight strips are tasks that were taught using CAI. The ability to generate flight progress strips is representative of many of the procedural types of assignments in the ATC field that must learned by the entrant controller. These ATC procedural tasks must be so ingrained that they can be carried out to automaticity and the strengths of the CAI forum may help to develop this automaticity.

Moreover, as ATC training is skirted to academe and the private sector, new and innovative approaches must be devised to increase the efficiency and effectiveness of the ATC training process. Accordingly, this research appraises the operational effectiveness of computer-assisted instruction as a possible part of university ATC instruction.
Review of Related Literature

Over the past three decades there has been an increase in CAI to teach new information, provide practice and feedback, and simulate or model complex concepts or events. "In recent years computer literacy has expanded extensively throughout the military, industry, and general populous. Due to this expanded literacy, CAI is becoming a very effective type of media available to the instructional developer" (Park & Montgomery, 1986, p. 19).

At the very least, computer technology is playing a key role in transforming existing educational and training systems toward an instructional delivery that, in some cases, is more appropriate for each student (Hannafin, Dalton, & Hooper, 1987). Recently, students have had the option of studying for and taking standardized tests such as the Graduate Record Examination on computer and receiving their results immediately (Stout, 1992). It seems that in some cases computer-based instruction compares favorably with traditional instructional and testing practices. Chambers and Sprecher (1984) found that CAI was more effective than traditional educational styles. In addition, a review of 51 studies conducted by Kulik, Bangert, and Williams (1983), found that students in classes taught with the CAI approach scored in the 63rd percentile compared with students taught by other methods that scored in the 50th percentile on final exams.

The Superintendent of the FAA training academy, Dr. Bartanowicz (1991), states that because of advances made in CAI and because there exists a real need to effect the level of ATC training, the ATC/CAI approach is already being implemented at the Federal Aviation Administration (FAA) ATC training facility in Oklahoma City. Bartanowicz also claims that the Academy is reflecting many technological changes that utilize the computer medium as an efficient and effective instructional delivery system. This author states that
once a valid job task analysis defines what the requirements for ATC training are, students can master the information in much less time using the interactive CAI approach.

Tyler and Goodlad (1979) reveal that the true role of universities and pedagogy emerge from a continuing sociopolitical process by which various educational conditions are deemed as unsatisfactory and others, more desirable. In other words, the job of instruction is to get the student from where they were before instruction to where they should be after the instruction takes place. The gap between these two sets of conditions provide the goals and ends to be accomplished. The instruction must also be related to the student in the most efficient way possible.

In the ATC training arena, as in other educational fields, it is prudent to employ the most effective means in order to achieve positive educational ends. CAI could be a constructive way to effect affirmative growth in ATC training. There is, however, scant research that note the effects of CAI on ATC student achievement. Perhaps this CAI/ATC classroom can enable the perspective student to better evaluate the suitability of pursuing an ATC career and better prepare the student to excel as an air traffic control specialist.

**Effects of Instructional Design on CAI**

Computers may be capable of contributing to the educational process in many ways, but by itself the computer is of little value (Hannafin & Peck, 1988). Experts in the field of CAI have stressed for some time that success in the CAI lesson depends upon adhering to accepted principles of instructional design (Hazen, 1985; Kearsley, 1984). Educators are also finding that by employing instructional design (ID) system procedures, educational software can be more meaningful, and effective (Hannafin & Peck, 1988).
Incorporating well-established principles of educational research and theory into the design of the CAI lesson serves to maximize the lesson's effectiveness.

There are many models to help guide the designer through the process of developing efficient and effective instruction with great user appeal. Reigeluth (1983), categorizes and defines three instructional outcome classes:

The **effectiveness** of the instruction, which is usually measured by the level of student achievement...

The **efficiency** of the instruction, which is usually measured by the effectiveness divided by student time and/or by the cost of the instruction (e.g., teacher time, design and development expenses, etc.), and

The **appeal** of the instruction, which is often measured by the tendency of students to want to continue to learn. (p. 20)

The ID model suggests that "instruction is the solution to a problem....this technique focuses on 'what is' and 'what should be' in a particular [educational] situation" (Dick & Carey, 1990, p. 13).

Romiszowski (1984), suggests that in the design of instruction there are four levels. These four system levels are distinct and separate.

**Level 1.** The project level - final objectives, principle measures, and constraints.

**Level 2.** The curriculum or course unit levels - detailed objectives, sequence, and content.

**Level 3.** The lesson plan level - the 'instructional events' that take place at each stage in a lesson.

**Level 4.** The learning step or individual exercise level. This implies that a given lesson is planned in detail and written out in some form of script or self-instructional material. (Romiszowski, 1984, p. 52).
Romiszowski's four level interrelationship is noted in figure 2

<table>
<thead>
<tr>
<th>Level of analysis</th>
<th>Chief outcomes at this level of design</th>
<th>Instructional decisions commonly made at this level of design</th>
</tr>
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<tbody>
<tr>
<td>1 Job analysis</td>
<td>Final objectives</td>
<td>Final evaluation system</td>
</tr>
<tr>
<td>Subject analysis</td>
<td>Tasks to teach</td>
<td>Syllabus content</td>
</tr>
<tr>
<td>Front-end analysis</td>
<td>Topics to teach</td>
<td>Overall sequence of units in course</td>
</tr>
<tr>
<td>2 Task analysis</td>
<td>Intermediate objectives</td>
<td>Formative evaluation system</td>
</tr>
<tr>
<td>Topic analysis</td>
<td>Prerequisites</td>
<td>Diagnostic test</td>
</tr>
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<td></td>
<td>Task/topic structure</td>
<td>Curriculum structure</td>
</tr>
<tr>
<td>3 Knowledge and skills</td>
<td>Enabling objectives</td>
<td>Sequence of lessons</td>
</tr>
<tr>
<td>analysis</td>
<td>Type of learning for each objective</td>
<td>Selection of methods &amp; media</td>
</tr>
<tr>
<td>4 Detailed analysis of the</td>
<td>Exercise design for each learning step</td>
<td>Detailed lesson plans</td>
</tr>
<tr>
<td>learning behavior/problems</td>
<td></td>
<td>Instructional events for each objective</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Methods/media matched to each objective type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Programmed learning exercises in any suitable media including</td>
</tr>
<tr>
<td></td>
<td></td>
<td>text, hands-on, audiovisual</td>
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<tr>
<td></td>
<td></td>
<td>lecturer, computer</td>
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</tbody>
</table>

**Figure 2. The four-level design process**

There is also a similar generic design model established by Hienich, Molenda, and Russell (1985) that lead the researcher through an instructional design process of needs assessment and an analysis of instructional goals and refined statements and performance outcomes that focus on exactly what students will be able to accomplish when the instruction is completed. Gagne, Briggs and Wager (1992), promote an instructional design systems view that places an emphasis on learner analysis, cognitive strategies, and information presentation strategies. The systems view also stresses the significance of motivational strategies to stimulate and inspire the student during the learning process.
Keller's (1987) attention, relevance, confidence, and satisfaction (ARCS) model synthesizes propositions and notable guidelines from several motivational theories. The ARCS model relates to the four categories of motivational conditions: attention, relevance, confidence, and satisfaction. The model assists the instructional designer through motivational learning theory and research so that during the instruction one can capture the student's attention, make the lesson highly relevant, and build learner confidence (Gagne, Briggs, & Wager, 1992).

The systematic approach in the design of instruction, entails following a succession of steps in hierarchical order. The systematic design strategy includes:

1. Needs Assessment
2. Defining Learning Objectives
3. Analysis of the Learning Task
4. Design of Instruction (and sequence of instruction)
5. Formative Evaluation
6. Summative Evaluation

The resources and procedures used to promote learning make up the instructional system. This system focus identifies specific learning outcomes, prerequisite skills, and suitable instructional strategies that are germane to the specific goals of the instruction.

**Needs assessment.** The first step in designing instruction is to identify one or more problems that the instruction can hopefully resolve, this is referred to as needs assessment. As stated earlier, in the next several years there will be a great influx of novice controllers. Creating a more efficient way to train these controllers sets the parameters of this particular needs assessment. A total understanding of the specific skills and knowledge that is to be gained, as well as who the learners are and what their specific needs are will
be addressed at this initial juncture. Specifically, needs assessment defines the area between what is, and what should be.

Learning objectives and task analysis. The abyss between what incoming students may already know about the subject matter (due to prior learning) and what they should understand about the subject, dictate the parameters of any course or educational module. The learning objectives define the specific purposes of the instruction; when converted to operational terms they become performance objectives. Performance objectives or learning objectives describe all the planned outcomes of the instruction and are the basis for evaluating the success of the instruction (Gagne, et al., 1992). However, there will inevitably be many unintended and unexpected outcomes as well.

Learning task analysis is inextricably tied to the instructional objectives. It is the task analysis that allows the instructional designer to determine the enabling and terminal objectives of the instructional task. Criswell (1989) suggests that all "specific objectives include (1) the conditions under which the student will perform, (2) the action required, (3) how the student will demonstrate the action, and (4) the mastery level required" (p. 58). After the course goals and performance objectives are agreed upon, the testing device can be prepared. Each test question relates to specific performance objectives.

Design of instruction. After the designer defines the problem, generates objectives by analyzing the learning task, and creates the testing device, one must identify the best sequence in which the objectives will be met and then design the instruction. It is during this development stage that storyboards are created and the appropriate sequence and frame design is assessed. Each storyboard reflects a specific learning objective and there may be many storyboards to meet any one objective. Storyboards are pages of paper that
resemble each computer screen viewed by the student. These summary sheets reflect how areas of knowledge will be presented and exhibited and contain a description of all the text and graphics to be included in the CAI module. Proper frame layout must also be considered during the design stage. Determining proper frame layout or flowcharting the lesson entails diagramming the possible paths through the various modules. At this time the entire lesson is on paper (Burke, 1982; Hannafin & Peck, 1988).

Formative and summative evaluation. Formative and summative evaluation both address issues of lesson effectiveness. Prior to programming the CAI module, the instruction and the feedback are evaluated by subject matter experts and the instructional design team. This meeting of the minds furnishes the instructional designer with material for initial revisions (Purcell, 1984). This preliminary evaluation identifies lesson features that require modification. Once the revisions are implemented, authoring the computer lesson may begin by taking the written instructions or storyboards and transferring them to the computer screen. This is accomplished with a programming language such as BASIC, or an authoring language, such as COMMON PILOT or PLATO. Another authoring option is the menu-driven software of the authoring system such as CDS 1, Linkway, or Authorware Professional (Burke, 1982). Converting the lesson from the storyboards to this authoring system may proceed after a formative evaluation consisting of one-to-one, small group, or field test evaluations. The formative evaluation identifies lesson features that require modification or revision.

Once testing and debugging and all revisions are complete the summative evaluation process decides whether the lesson will be adopted. The summative evaluation process determines the value of the lesson and is used to validate performance rather than identify areas of the lesson that need improvement.
Summary. Worthwhile instruction is based on a systematic process that can generate a predictable outcome. Friedman, Polson, and Spector (1991) recently disclosed that an automated instructional design guidance system has been developed for computer-based instructional materials. The Advanced Instructional Design Advisor (AIDA) assists experts in the complex and time consuming process of producing effective computer-based instructional materials. Though still in the research and development stage, AIDA may have a profound effect in automating the instructional design process.

The instructional designer that utilizes the computer as the medium for instructional delivery adheres to many components of learning theory to facilitate efficient and successful learning. To improve instruction, the instructional process must be improved. The established way to accomplish this task is through the use of well defined and well founded systematic instructional design constructs and models.

Making CAI Successful

The design of CAI systems are usually based on educational research, on intuitive knowledge of effective teaching and learning, and on pedagogical considerations of the specific subject matter involved (Hativa, 1991). This does not automatically infer that every CAI experience has been beneficial however. Foshay (1986) suggests that much computer-based instruction resembles computerized programmed instruction. Gleason (1981), slices a little deeper, stating that most CAI is "devoid of any instructional value..." (p. 12). Gleason goes on to note that much computer-based instruction acts as a deterrent to widespread acceptance as a valuable medium of instruction. It is the job of the instructional designer, therefore, to find out what the strengths of the computer are and accentuate the positive. The question must be answered, what makes CAI successful?
The teacher factor. Although there is no standard criteria for evaluating the success of CAI, experts agree that as in the case of traditional instruction, the teacher variable is the biggest contributing factor to success or failure of the CAI system (Sugrue, 1991). The computer, in and of itself, is no panacea of educational promise. Sugrue quotes Charp, stating that "even after 25 years of CAI, educators are still looking for the magical innovation that will dramatically change what we teach and how we teach it" (Sugrue, 1991, p. 35). Therefore, it is somewhat surprising that the failure to implement a greater amount of CAI in the university classroom can be "traced to an unwillingness on the part of the faculty to abandon the direct control of the instructional process which they maintain in traditional teacher-centered methods" (Reeves, 1991, p. 63). Many professors do not realize that they can relinquish tight control of the class while creating and incorporating their own computer-assisted instruction in the classroom.

Gery (1987) states that excellent CAI is produced by relatively inexperienced people only when they are provided with the right education, development, structure, and coaching. "The key is to be specific in your development and support plans and not to use hope as a strategy for skill and knowledge acquisition" (p. 167). It should be noted that the university should directly support the creation of CAI. Also, the management and organization of resources is at least as critical as the skills of the instructors.

The elaboration theory. Within the field of instructional design, certain methods are used that improve the techniques that make instruction more effective, efficient, and appealing. The elaboration theory of instruction is just such a method. This technique prescribes that the instruction start with a simple overview, teaching a few general fundamental ideas. Subsequent instruction presents a progressively detailed analysis of earlier concepts (Reigeluth & Stein, 1983).
The elaboration theory also suggests that all parts of the instruction continue with the simple-to-complex sequence analogous to a zoom lens on a movie camera. The student starts with a wide-angle view, allowing that student to see the whole picture with all of the relative relationships but without the distracting and confusing detail. The person then zooms in on a discrete part of the picture. After studying the subparts and their specific interrelationships the student zooms back out to the wide-angle view, further reinforcing a given area as part of the much larger whole. In addition, elaboration also proposes that instruction should further be sequenced so that the individual is initially presented with the epitome of the concept or idea. Therefore, the student will first view the simplest form of the principle to be learned, then elaborations of that principle will be presented. Each successive example becoming a little more complex; always from the general to the specific. This simple-to-complex, zoom-in zoom-out approach helps ensure that the meaning and appropriate context of each learning segment is fully understood and internalized (Gagne, Briggs, & Wager, 1992).

**Games: Another learning framework.** No instructional method can be expected to receive universal acceptance, but instructional games can provide an effective framework for many learning situations. As long as the game provides the actual practice of the intended academic skill, student interest, motivation, and learning all increase. The drill-and-practice method of learning can become quickly tedious but is especially well suited to the gaming approach. The score becomes a benchmark that the student uses to judge past and future performances (Heinich et. al., 1989).

**Informational mapping.** There are many ways to make information available to the CAI student. Improving the information transfer can be the first step in making CAI
successful. One way that has shown promise in making CAI more effective is informational mapping. By definition, informational mapping of instructional text is "a methodology for analyzing, organizing, writing, sequencing, and formatting information to improve communication" (Horn, 1989).

The informational mapping method provides a structure through the subject matter that can be useful to the student as it simplifies the instructional communication process. Informational mapping provides the instructional designer with a paradigm that helps identify, categorize, and interrelate the information required for efficient learning to take place (Horn, 1969). The process entails breaking each frame into parts that can easily be recognized by the learner as the topic found in the margin of the frame and the text found to the right of each topic. By utilizing this method, topics are listed in these margins or presentation blocks, and a greater explanation of each topic found to the right, in its own block of text. This provides each student with the freedom to identify the topic area, question the need for this information, and read only the text that needs further clarification.

This presentation format is simply another framework in CAI approaches. The use of headings and other reference features help improve the presentation of information. Identification of the types of information that are available are noted in marginal areas outside the presentation blocks. A consistent format is used for each topic. Functional and uniform headings and sub headings are used to speed up reference work and to make scanning for necessary information easier (Horn, 1989).

Each information map begins on a new page and feedback questions and answers are located in close proximity to the relevant informational maps. The subject matter is further broken down into its component parts for more thorough understanding of the information. Finally a local index of related pages provides quick location of prerequisite
topics. Utilizing the informational mapping method can be beneficial in designing less complex and more effective computer-based instruction (Horn, 1976).

In CAI, the pace of the instruction is primarily controlled by the student. In a hypertext environment any frame can be accessed by the student at any time in the instruction. The increased one-to-one nature of this type of CAI makes it possible for each student to personally evaluate mastery of the subject matter continuously and exhibit singular control over the instruction. In highly interactive CAI, instruction can be better able to respond to the needs of each individual student (Dence, 1980; Ross, 1984). A curriculum design focused on individual needs has unique characteristic features.

Saylor, Alexander, & Lewis (1980), suggests that the instructional plan should be based on a knowledge of learners' needs and interests, involving a diagnosis of the specific needs and interests of the students that are to be educated. Computer-based instruction should remain highly flexible, with built-in provisions for development and modification to confirm to the needs and interests of particular learners and with as many options available to the learners as possible without getting too confusing.

The student should also be consulted and instructed individually at appropriate points in the curriculum and instructional process (Saylor, Alexander, & Lewis, 1980). However, one detriment of so much freedom, is the ability to get lost in hyperspace (i.e., so deeply enveloped by a series of CAI frames that getting back out seems impossible). This problem is usually only experienced in the hypercard applications of computer-based instruction. Horn (1989) offers valuable guidelines in organizing information in hypertext applications. It should be noted that the same hypercard programs that allow greater user freedom also permit novel instances for confusion and frustration on the part of the student due to the very nature of the hypertext environment.
Interactivity of the computer medium. There are many changes evident in the field of educational technology and of the most dynamic is the use of CAI. However, to successfully implement the computer as an educational tool, research asserts that the instruction must actively involve the learner. Borsook and Higginbotham-Wheat (1991), suggest that more interdependence between computer and human during the learning process will make the most of the unique instructional potential of the computer, and they offer a menu for success in how to successfully implement CAI in the curriculum. The authors contend that the critical elements of successful CAI relate to increasing the interactivity of the computer medium; the software should not simply imitate an electronic page turner. The writers imply that instead the computer must seem to disappear and be replaced by an entity whose own responses are highly related to the user's input.

Borsook and Higginbotham-Wheat go on to note that the recipe for interactivity in CAI begins with tailoring the communications to the individual learner. The messages should be receiver-specific, that is, the responses must be based on the feedback of each learner. This type of interaction utilizes a two way flow of information to accommodate this feedback. To be successful, the computer program should present information and then be able to branch to the appropriate locations in the material depending on the individual response of the learner. The concept should be able to be restated in a different way if necessary, this serves to make the software more responsive to the needs, concerns, and anxieties of the learner audience.

The key ingredients of interactivity only begin with personalizing the instruction. Interactivity must include immediacy of response, where the student can receive text elaboration by a simple and effective click of the correct key. Effective feedback also allows the interactive systems to adapt instruction to a specific learner. Hooper and Hannafin (1988) conclude that it is such "feedback that provides the source with the
information concerning his [the student's] success in accomplishing his objective. In doing this, it [the computer] exerts control over future messages which the source encodes" (pp. 111-112).

Smith (1972) and Gery (1987) suggest that it is not enough for the feedback package to state that an answer is simply right or wrong. If the incorrect answer is given, the feedback must include directions on how to correct the situation. Success by the learner in accomplishing the objective is verified by this feedback. When designing the CAI module it is important to keep the length of time of any given sequence down to a minimum and to try and maximize the two-way communication. These techniques are agents that help create a unique instructional system that increases interactivity.

The way that the student interacts with the computer and how hands-on that interaction is, has a significant effect on interest and motivation. Negroponte and Bolt, made an experimental environment at MIT that utilized a varied number of information environments. This experimental Dataland, as it was called, enabled the operator to switch around in hypermedia freely with the use of joy sticks, touch screens to navigated in the information space, computer screens took up entire walls, speech recognition systems moved the cursor, and loudspeakers surrounded the room. The student's divergent thinking was an asset that manipulated the computer environment as they wished (Horn, 1989).

It is acknowledged by experts in the field that efficacy and efficiency of learning as well as motivation, can be increased by allowing the learners greater control of their own instruction. However, there is the phenomena called the too much rope syndrome (Borsook & Higginbotham-Wheat, 1991, p. 13). Studies reveal that for most learners, when the locus of control shifts from the computer to the student, this too can negatively impact interactivity; giving the students just enough rope to hang themselves (Grey, 1977;
Higginbotham-Wheat, 1990). Interactivity is a complex process that changes from one learner to the next and from one training regime to another.

Selnow's critical features of interaction aid the instructional designer realize the ever-present and significant features that are present in all beneficial interpersonal communication. This author contends that it is the richness of this human-to-human interaction that should be the goal for computer-to-human interaction (Selnow, 1988). Making CAI a richer experience between computer and student, is a powerful and constructive aspiration for the computer-based instructional designer.

Berlo's levels of communicative interdependence help explain that in effective programming, the source affects the receiver just as the receiver must always be able to affect the source. This increases interaction and action-reaction interdependence. The learner must have the opportunity to give the computer feedback so that the responses are highly related to the user's input. As Berlo (1960) explains, these are concepts that are well founded in human-to-human communication model theory, but rarely practiced in present day CAI.

These interactivity guidelines assist the instructional designer in creating instruction that is dynamically adaptive to learners idiosyncrasies. Gery (1987) contends that interactivity is CAI's raison d'être. The challenge for the designer of computer-based instructional materials is to fully "understand interactivity, define it, create it, push the limits of current thinking and development tools, and make interactive CBT happen" (p. 42). In the totally interactive CAI environment, the student should ideally be free to explore, with learner control convenient and accessible. The completely interactive CAI educational situation should be a risk-free environment in which the student can experiment, interact with the learning environment, make mistakes, and learn.
Summary for CAI success. Many different facets of educational learning theory must come together in order to achieve valuable and efficient instruction. Gagne, Wager, and Rojas (1981) suggest that it may be prudent to develop instruction in accordance with the internal processes of learning that are based on the nine different phases of the learning cycle: (a) alertness, (b) expectancy, (c) retrieval, (d) selective perception, (e) semantic encoding, (f) retrieval to working memory, (g) reinforcement, (h) cueing retrieval, and (i) generalizing. These authors recommend that an instructional event should be associated with each of these nine phases of learning to ensure that the corresponding internal learning process is stimulated. Gagne contends that a greater degree of confidence in the mastery of the subject matter can be obtained by including some of these nine events of learning.

Gagne, Briggs, and Wager (1992) offer a checklist of Gagne's nine events of instruction that is perhaps the most helpful rule of thumb in designing successful CAI. Gagne et al. maintain that the instruction should include a set of events external to the learner that are specifically designed to support these internal processes of learning. In figure 3, the external instructional events are related to the internal processes of learning.

<table>
<thead>
<tr>
<th>External Instructional Event</th>
<th>Relation to Internal Learning Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gaining attention</td>
<td>Reception: Gain alertness and interest</td>
</tr>
<tr>
<td>2. Inform learner of lesson objectives</td>
<td>Focus mental effort</td>
</tr>
<tr>
<td>3. Stimulate recall of prior learning</td>
<td>Retrieval of prior learning to working memory</td>
</tr>
<tr>
<td>4. Present stimulus material distinctively</td>
<td>Emphasize features for selective perception</td>
</tr>
<tr>
<td>5. Provide learning strategy</td>
<td>Semantic encoding; cures for concept retrieval</td>
</tr>
<tr>
<td>6. Elicit performance during lesson</td>
<td>Active response; retrieve lesson information</td>
</tr>
<tr>
<td>7. Provide informative feedback</td>
<td>Establish reinforcement and confirmation</td>
</tr>
<tr>
<td>8. Assess performance during lesson</td>
<td>Associate lesson concepts with lesson objective</td>
</tr>
<tr>
<td>9. Enhance retention and transfer of lesson information and concepts</td>
<td>Provide cues and strategies for later retrieval; generalize and relate current lesson information</td>
</tr>
</tbody>
</table>

Figure 3. Gagne's Nine Events of Instruction
If many of these nine events are introduced to the learner in the CAI presentation, effective and interactive learning is more likely to occur. All of the nine events do not have to be present, nor do these external instructional events need to be in exact sequence.

Finally, Hannafin and Peck (1988) propose that CAI works best when instructional objectives are well specified, when interaction is maximized, and when the instruction adapts to the needs of the students and fits the educational environment. If some or all of these characteristics are adhered to CAI has a better chance of being successful. As time passes, however, the promises of CAI are becoming more realistic and the caveats accompanying computer instruction, more specific (Sugrue, 1991).

**Advantages of CAI**

The use of computers in educational and industrial training environments is escalating and there are many strong advocates of computerized training. Used in its most effective context, CAI may have advantages over conventional educational media. In cases where CAI is warranted, positive features may include greater individualization and motivation, immediate feedback, learner control, and lesson integrity. Another advantage of effective CAI is that it stimulates interaction and has the ability to maintain student involvement (Bright, 1983; Caldwell, 1980).

Clement (1981) states that there are varied reasons for the motivating and appealing effects that computer media has in the classroom. Brophy (1981), submits that learning from computers pose less of a threat to the students than learning from the more critical professor. It is also motivating for the student to be able to control the pace of the lesson and exhibiting a certain amount of control over the instructional process (Hannafin, 1984). It is imperative that CAI be motivating, as Davies (1973) notes, the student should possess a general willingness to enter into the learning situation and student motivation.
should be "developed and harnessed during the learning process" (p. 150). It should be understood that any learner in the CAI environment should be attentive and responsive to the computer as a teaching/learning tool. Often, however, this is directly reflective of the quality of the CAI design.

The administrative strengths of the CAI approach are also diverse. Some strengths include cost effectiveness, ease of record keeping, and the possibility of teaching a group of students with little or no supervision (Hannafin & Peck, 1988). Shlechter (1991) divulges that although there are many promises of CAI some of these promises do not match what has occurred in reality. Overall, adding the computer-based medium to instruction was originally expected to improve the American educational system in four distinct ways (Shlechter, 1991). First, CAI promised to stabilize educational costs. Second, student achievement was thought to increase. Thirdly, it was felt that CAI could handle individual differences and needs more effectively. Lastly, student motivation was expected to increase. A pervasive contention of CAI is that the "program is easy and fun to use .... [and] might also help students be more creative (Shlechter, 1991, p. 11). However, decades later, many of these expectations have still not been realized.

Herein lies a caveat in the debate for CAI in education. Specific applications can rarely be generalized to the whole. Clark (1983), Shlechter (1988), and Levin (1988) all find that the more conservative view of the promises of CAI are perhaps more realistic.

**CAI and educational costs.** It has always been an expectation that the computer in the classroom could provide instruction to more students without greatly increasing instructional personnel (Wilson, 1991). The Office of Technology Assessment (OTA), (1988) reviewed many cost-effectiveness studies and concluded that in specific cases computer-based instruction can be more cost effective than nontechnological methods of
instruction. However, the OTA also noted that this cost-effectiveness is extremely sensitive to the particular instructional characteristics of the participating educational arena. One certainly cannot issue a blanket statement that computer-based instruction is more cost effective than other types of instruction in every situation.

Unfulfilled Promises of CAI

In educational situations there are various reasons that the beneficial features of CAI do not come to fruition. Unfortunately, in many cases, the educational system must overcome inadequate funding including a lack of support personnel and insufficient teacher training. Inadequate software is another fault of many CAI systems. Instructors are rarely consulted in developing commercially published software and thus remain "out of the loop" in software construction (Shlechter, 1988). Above all, inadequate planning and preparation is perhaps the most frequent downfall in successful CAI execution.

There are also drastic organizational changes that occur vis-a-vis CAI implementation and in many educational environments the coordination that is necessary is found to be insufficient. Finally, unrealistic expectations further inhibit CAI success. Just as outlandish claims were made of programmed instruction, CAI is thought by some to be the next educational panacea. When these hopes are not met educators become discouraged with the technology altogether (Shlechter, 1991).

Proponents of CAI cite many studies indicating that CAI improves performance levels on standardized achievement tests (Kulik, Bangert-Downs, & Williams, 1983), and enriches higher order thinking skills (Pea, Kurland, & Hawkins, 1985). However, Clark and Sugrue (1988) note that most studies on CAI have severe methodological flaws and that the observed achievement gains can be accounted for by novelty and instructional design variables that are independent of the CAI module. Becker (1987), suggests that
most of the CAI evaluation literature is, therefore, fragmentary and cannot be generalized beyond the sphere of schools in which it was conducted.

In pointing out the advantages of CAI along with some of its possible barriers, it should be understood that the computer offers the potential, but does not guarantee to reform learning for many students. The computer is only a tool, and as such it can be restricted by poor planning and substandard management practices. Unleashing the potential of CAI hinges on a dogmatic attention to curriculum design principles and implementation practices to overcome the common restrictions associated with its use.

**Weaknesses of CAI**

Like many instructional delivery systems CAI's disadvantages, if unchecked, could curtail much of the medium's effectiveness. The sagacious instructional designer, understanding these limitations can minimize their impact.

One of the main disadvantages of CAI is that the instructional endeavor must be performed on expensive computers that may not be available to the student at home. This restriction causes students to utilize the computers at the school computer lab, and often this hardware is already being used for word processing functions. Availability is a key issue in CAI outside of the classroom. The software also has its limitations in that it can be executed on specific hardware equipment only. In addition, students may have difficulty reviewing the subject matter away from the school learning environment if access to a computer is denied them. The student can print a hard copy for lesson review and this may overcome some of this accessibility flaw.

The majority of the course content of CAI systems is on the video display and this places a heavy burden on the student's reading and visual skills. Hopefully the software allows the student to control the pace of the instruction and therefore the student can
exert more control over any inherent lack of reading speed and comprehension. However, if the student's reading ability is deficient, effectiveness of this medium could be significantly compromised.

Accordingly, if the computer screen is of low quality, certain text and graphics can be of such poor resolution so as to defy comprehension. No matter how well defined the resolution, the display images often cannot compete with other media representations. However, it is possible to incorporate the more realistic images of other media to offset the disabilitating influence of the video screen in certain situations. As computer technology gets more refined, and screens get larger, with higher resolution and with greater control over color, CAI will continue to experience more freedom in instruction.

The major educational goal is to prepare people to become productive members of a society that is progressively becoming less an industrial economy and more an information-driven economy. As the need for training and retraining mushrooms, computers will inevitably play a major role in this instructional process. It is, therefore, imperative that the inherent weakness' of CAI are minified whenever possible.

The Computer and Aviation

Computer-based trainers, simulation systems, and CAI have been used with varying degrees of success to enhance the effectiveness of training in many of the aviation disciplines. The U. S. Air Force employs over two hundred hours of CAI in Rockwell's B-1B program to train instructors and students (Staff, 1986). In addition, many civil, corporate, and commercial pilot training applications have been found for the computer-based approach to learning. Shifrin (1988) reported that American Airlines invested heavily in computer-based instruction to meet pilot demands. Nordwall (1988) contends that computers will continue to be used at the lower end of the pilot training
spectrum. However, mixed results as to the effectiveness of the computerized medium on learning was experienced by companies that train corporate pilots and some of these companies have gone back to the classroom lecture approach (Phillips, 1988).

On the other hand, the National Aeronautics and Space Administration (NASA) has long used computer-aided instruction to train astronauts, flight controllers, and ground-based support personnel. NASA contends that these CAI sessions provide meaningful comments in response to trainee errors, give information needed at the proper time to solve problems, and point out various student strengths and weaknesses' (Loften, & Savely, 1991).

At this juncture it is not certain that a blanket statement can be issued as to CAI's effectiveness in aviation and aeronautical pursuits. Altensee (1990) concurs, stating that recent experiments emphasize the need for further research to determine the proper design and use of computer-based instruction for maximum effectiveness.

Implementing CAI in Higher Education

The computer is no stranger to today's university as it assists in research, administration, management and communication practices. However, the computer has been severely limited in its instructional utilization (Heermann, 1988; Reeves, 1991) This is not surprising given the fact that the computer, like other technological innovations (i.e. the automobile, telephone, television), may require generations of evolution before its potential is reached (McClintock, 1988). However, Redish (1988) and others hold to the belief that the computer can restore creativity and individual flexibility to university subjects that have been stifled by years of repetitive and rigid instruction.

The effort of incorporating CAI in the university has thus far been thwarted by denying interested faculty a resource center of instructional design personnel, graphics
designers, and programmers to help them in their CAI efforts. Compounding the problem is the fact that most university professors are simply not familiar enough with CAI and it is inherently difficult for them to abandon direct control over the instructional process; a process that through years of didactic instruction they have grown most comfortable (Reeves, 1991).

There is a simple rule of thumb educators can use to assist them in effective CAI instruction. As mentioned earlier, Gagne's nine events of instruction (Gagne, Briggs, & Wager, 1992), may help the novice instructor through this initial process. Armed with this advice, the CAI instructor/author can identify nine external instructional processes that correspond to and engage nine internal learning processes of students (Hannafin & Peck, 1988; Gagne, Briggs, & Wager, 1992). Reeves (1991) believes that utilizing Gagne's nine events of instruction during each CAI episode would be most beneficial, but all too often CAI programs simply mimic the didactic orientation of instruction. This fault, Caldwell (1980) warns, recreates in CAI, the very worst of what occurs in traditional instruction.

Shneiderman (1986), pins the cause of this problem to instructional designers that develop instruction from the perspective of what the professor does to teach a course and not what a student does to learn it. This common downfall can be overcome by utilizing just the first three steps of Gagne's model "(a) grabbing the learner's attention (b) informing the learner of the lesson objectives, and (c) stimulating recall of prior learning. These first three events of instruction, are believed to elicit corresponding cognitive states such as (a) alertness, (b) expectancy, and (c) retrieval to working memory" (Reeves, 1991, p. 64). Reasons for being cognizant of the learners viewpoint to create meaningful instruction are well founded in basic principles of cognitive psychology and educational learning theory (Gagne, Wager, & Rojas, 1981).
It should be noted that the "publish or perish" atmosphere that permeates academe does little to stimulate CAI development in the university. The financial rewards that exist with authoring textbooks simply do not exist with authoring software. Intellectual work in digital form often goes unrewarded and frequently universities demand a share of any software publication profits (Reeves, 1991). If this climate does not change there is little reason to believe that, without incentive, valuable, interactive software will ever be generated by the professors most able to create it.

Recently, there has been a smattering of universities that have recognized software authoring as a legitimate endeavor for credit toward promotions and tenure. In most universities, however, authoring software is still considered a lesser contribution than development of a text. Before computer-assisted instruction is successful in the university classroom, increased recognition for those responsible for software development must be forthcoming (Turner, 1989).

Before one can set out to define curriculum parameters or design any course of instruction, it is important to clarify for whom the instruction is directed. In the university setting there exists an opportunity to further educate a person that desires and actively seeks this education; specifically the adult learner. This study takes place in a university setting and as such, the members of the university populace should be defined. An adult learner is one "who is enrolled in any course of study, whether special or regular, to develop new skills or qualifications, or improve existing skills and qualifications" (National Advisory Council for Adult Education, 1980, p. 3). It may be valuable to construct a profile of the university student so that the training program could reflect the needs and expectations of this unique individual.

Every adult is different, and as Gagne (1971) assures us, these differences are compounded by the varied stock of prior learning and experience that cohere into a
unique, idiosyncratic mediatory mechanism through which new knowledge is filtered. Hence, educators can never accurately predict with total certainty how any one learner will respond to new ideas, skills, or specific knowledge. Research does suggest, however, that the adult learner shares certain attributes such as: (a) learning must be problem centered, (b) goals must be set and pursued by the learner, and (c) the learner must have feedback about progress toward these established goals (Gibb, 1960).

Simpson (1980) further maintains that educational theorists also concur on one distinguishing characteristic of the adult learner; they inevitably exercise autonomous self-direction in learning. This self-direction in the learning process can be easily accomplished in a CAI hyper-card environment where the student can access at will, different areas of interest or parts of instruction that need more elaboration. This may also lead to other problems as the student may get distracted and even find it hard to get back to where they were in the CAI lesson. Simpson, asserts that presenting the adult with a more self-directed method of learning is to pass along the reigns of his/her own learning track; allowing the student to better control their own instructional path. However, recent empirical data somewhat discounts this idea claiming that total learner control is beneficial only to the brightest and most knowledgeable high achievers (Borsook & Higginbotham-Wheat, 1991; Higginbotham-Wheat, 1990; Ross & Morrison, 1988). In fact, Grey (1977) notes that too much control over the branching of instruction may lead learners to acquire negative attitudes toward the lesson. Too much of an imbalance by either the learner or by the computer can result in a compromise to the successful accomplishment of lesson objectives.
Summary

The challenge of educational technologists in the field of computer-assisted instruction is in assessing the status of this educational medium in order to reform and maximize this technology's potential and contribute to educational improvement for the wide spectrum of university students. Utilizing the systematic approach in the design of CAI could enhance the learning experience by delivering instruction that introduces novelty, challenge, and success experiences that can contribute to the students' enhanced curiosity, motivation, and perceptions of competence and worth (McCombs, 1991). Student retention following CAI modules may be comparable or superior to retention following other methods of instruction (Dence, 1980), however, this instruction must be individualized to meet various student needs.

In addition, the literature clearly suggests that well designed CAI can be at least as effective as other methods of instruction while being used in combination with other teaching methods or as the only means of instruction (Gleason, 1981). Often, CAI produces more learning in a given period of time or produces the same amount of learning in a shorter period of time, when compared to other forms of instruction that do not account for individual differences (Bright, 1983; Gleason, 1981).

When comparing the advantages of CAI to alternative modes of instruction Branson (1991) asserts that computer-based training should allow the student to reach criterion more quickly, be less costly, be more effective, provide higher quality instruction, be more versatile and be preferred by users. Branson further admits that computer-based instruction will have to be successful in each of these areas if the computerized instruction is to reach full potential.

Podemski (1984) warns that by denying computers their place in education, *tradition-bound* teachers could be dooming the very educational system they long to save.
Failure to conscientiously utilize the computer technology as an effective instructional forum may cause students to question the viability of traditional instruction, which, in turn, could lead to a rejection of the current university educational system. Podemski foresees CAI supplanting present educational and instructional systems, becoming a significant, viable and more efficient alternative to traditional educational delivery systems; assisting, but not replacing educators and teachers.

If the problems as well as the promises of CAI are kept in mind during the design process, many drawbacks inherent in computer-based instruction can be kept to a minimum. The advantages of the computer medium can be accentuated by efforts that increase interaction, motivation, individualization, immediate feedback, and learner control. The literature also suggests that utilizing systematic instructional design practices in the development of CAI enables the instruction to be better planned, organized, and controlled.

The use of systematic instructional design also enables learning activities to be properly managed and sequenced. Without the systematic approach to the design of instruction it is very difficult to compel instructional events to conform to preconceived plans (Davies, 1973). It is through strict adherence to the ID model that the outcomes of the computer instruction can become predictable and productive. These predictable learner outcomes are directly related to the acknowledgment of the precise and clearly defined elemental building blocks that make up the instruction (Reigeluth, 1983).

By designing the CAI episode utilizing systematic, goal oriented principles of instructional design and interactivity, the student may become more engrossed in his/her own ATC training process. Parenthetically, it is unwise to make the student a passive receipt of processed information when the learning endeavor can be one in which the student is critically and creatively involved.
Statement of the Hypothesis

In this experimental study, it is hypothesized that there is a significant difference in student achievement between university ATC students that receive computer-assisted instruction and those university students who receive instruction by the traditional didactic method. It is also hypothesized that incorporating computer-based training that utilizes principles of instructional design will increase learning and retention. It is anticipated that this study may lead to a more effective method of training ATC candidates in the University program.
**Method**

**Subjects**

This study was conducted in the ATC classroom at Embry Riddle Aeronautical University (ERAU). The sample for this study was taken from students enrolled in the AT 364 ATC course at ERAU in the fall term, 1992. This class was offered to all students that had successfully completed AT 362, an introductory course to air traffic control. These were average students enrolled in various university aviation science courses. These students enrolled in the ATC courses in order to further augment their aviation education. The samples are representative of their respective populations and similar with respect to other critical variables. Only the method of instruction was dissimilar. The entire sample was comprised of 25 students (four female and 21 male).

Specifically in this study, the CAI was confined to the tasks of identifying, interpreting, and generating three types of terminal flight strips (terminal, arrival, and overflight). There were a total of twenty-five students enrolled in AT 364 during the fall term. To arrive at a completely random assignment of subjects, this researcher employed a random number generator which is a computer program that utilizes a seed number to arrive at the two groups of students. This computer program, written in the "C" programming language (Appendix A), generated two groups of numbers from 1 through 25. The first thirteen students were chosen by the computer using this random assignment of subjects and these students received the experimental treatment (computer instruction). The remaining twelve students served as a control group and were exposed to the regular lecture method of instruction during the flight strip unit of study.
This type of "randomization is effective in creating equivalent representative groups that are essentially the same on all relevant variables thought of by the researcher" (Gay, 1992, p. 315). The random number generator program controlled for many extraneous variables and was used to control for many sources of internal and external invalidity as well.

**Instrument**

The effort to improve instruction, making it more appealing, effective, and efficient, is the goal of all educational organizations. The use of CAI to motivate and support student learning and retention, has been attempted throughout the U.S. and Europe for the past three decades with contradictory results (Sugrue, 1991). Unfortunately, much of the past CAI was developed by individuals that had little instructional design experience and/or the modules were devoid of effective interaction including efficient and productive drill and practice regimes. This experimental study compared the posttest results of the lecture and CAI students that had completed the flight strip marking unit, thereby establishing a relationship between learning and retention utilizing two very different methods of instruction.

This study was limited to all of the students that had enrolled for AT 364 and as such, this experiment was limited to a sample of a given size. The entire class of twenty-five AT 364 students were randomly assigned to one of two groups and then exposed to the independent variable (CAI or lecture instruction), and posttested. A pretest was not used as both groups exhibited relatively the same amount of prior knowledge of the dependent variable (generating, interpreting, and updating flight strips) and mortality during the one week classroom experience was not perceived to be an issue. In fact, there was no mortality in this study.
The unit test on flight strip marking was conducted at the conclusion of the one week flight strip marking module. The posttest scores were analyzed using the analysis of variance (ANOVA). Though the students were assigned to the instructional treatments at random, the use of randomization alone does not necessarily guarantee that both groups were equated on all variables. Readiness to learn flight strip marking, individual I.Q., and specific aptitude, could not be controlled for in this specific research study. The ANOVA was utilized so that this researcher could decide whether the variation between means was greater than that expected from random sampling fluctuation alone. Ferguson (1989) clearly states that "one advantage of the analysis of variance is that reasonable departures from the assumptions of normality and homogeneity may occur without seriously affecting the validity of the inferences drawn from the data" (p. 246).

The unit test raw scores were used to determine the effect that CAI (the independent variable) had on learning and retention of flight strip marking rules and procedures (the dependent variable). The unit test was a supply the answer type of test composed of 33 questions (Appendix C). These questions were directly related to the flight strip marking issues that were taught during the lecture and computer-assisted instruction. This posttest was submitted to all of the students at the end of the flight strip marking instruction on the fifth week of class.

The ANOVA reveals the significant difference that exists between the experimental and control groups, and specifically which group achieves significantly different grades. Comparing these posttest results determines the effectiveness of the instructional treatment. Finally, the compilation of the unit test (posttest) scores, provide sufficient amount of data to adequately test the research hypothesis.
Design

This study utilized the posttest-only control group design. Specifically, it was the purpose of this study to determine the effect that CAI had on learning and retention for university students enrolled in upper level ATC classes. However, there are restrictions that compromise the generalizability of this study. Students at the university level choose their classes depending on a specific schedule and allotted time for each class. The initial population from which the subjects for this study were chosen already existed, could not be randomly selected, and may very well have differed on some variable unknown to this researcher. However, the individual ATC classes selected for this study were as homogeneous as university students can be and no extraneous variables are noted.

The subjects were not told that they were part of an experiment as this might have introduced other unwarranted variables into the study. For example, if the students knew they were being scrutinized, they may have altered their study habits or testing techniques. The students, therefore, were not aware they were involved in a study and hopefully, this minimized any deleterious consequences of a Hawthorne effect.

No sample is completely representative of the population from which it is drawn. However, certain physical controls were present throughout this study to encourage a greater experimental validity. The same teaching staff was present for each class and the class size and class times also remained the same. With this in mind, it is believed by this researcher that this study is generalizable to ATC university populations.

Computing the differences between the means of posttest scores for the control and experimental groups determined the effectiveness of the instructional treatment and tested the research hypothesis. This approach was considered applicable primarily because flight strip marking was a new skill to all AT 364 students. Therefore, it is expected that all students will likely have the same amount of room to gain.
Procedures

In the fall term of 1992 there was a single class of AT 364 students that had already successfully completed AT 362 which is the survey course for air traffic control. The students in AT 364 learn ATC procedures, ATC operations, flight strip marking, controller phraseology, and aircraft separation standards. The instruction and subsequent unit tests culminate with a computer simulated environment in which the students experience controlling air traffic in a specific sector of computerized airspace. Flight strip marking is an important part of the AT 364 course as the flight strip contains all the data on each aircraft and denotes any changes made in the route of flight information. To direct air traffic safely and efficiently, flight strips must be constantly referred to and their contents quickly assimilated and/or revised.

On the first day of the flight strip marking unit the class was divided into two groups consisting of thirteen students in the experimental group and twelve students in the control group. The selection had already been accomplished by random computer assignment. The experimental group met in the computer lab for two class meetings and the control group met in a lecture classroom. The instruction continued as determined by the individual instructor responsible for each class. At the end of the flight strip marking unit a posttest was administered to each class and the results tabulated for data collection. The posttest results were then analyzed and an analysis of variance tested the significance of differences between the means of the two groups.

The null hypothesis states that there is no significant difference between the means of the posttest scores of the control and experimental groups. The unit test data was the instrument used in determining the effectiveness of CAI to instill the knowledge required to maintain flight strip data in the dynamic ATC environment. The results can be used to determine the efficacy of CAI in this and perhaps other ATC training applications.
Analysis

This comparative research study identifies relationships between method of instruction and effects on learning and retention of basic ATC flight strip marking skills and procedures. The comparison between the CAI and the lecture classroom also identifies instructional variables that may be worthy of future experimental investigation in other university coursework. The statistical results of this study reject the null hypothesis that states there is no significant difference between the two modes of instruction in the ATC training regime.

It is appropriate at this time for this researcher to include a statement of limitations of the statistical analysis. This is an initial study therefore the ANOVA was used so that this researcher could gain experience with this type of statistical method. A "T" test could have been utilized, however, the data gained from an ANOVA is usually considered to be more robust and more reliable. This researcher felt that one could have more confidence in the results from an ANOVA statistical analysis.

As one must be cognizant of the fallibility of the ANOVA statistics in this specific instance, a caveat is offered. There are many things that cannot be controlled for in this study. The population from which the experimental and control groups were chosen had already been selected. Alluded to in previous sections of this thesis is the fact that students choose their own classes. Consequently, the population and sample in this study were not randomly selected, though students in the experimental group and control group were randomly selected from this sample. It is therefore noted that these uncontrolled variables may place limitations on the ANOVA data and contribute to sampling error.
It is cautioned that these data reflect only the differences in learning and achievement between the flight strip marking lecture class and the computer-assisted flight strip marking class. It is not the purpose of this study to compare the gains in learning and achievement of all types of lecture with the many different types of computer-assisted study. It is further noted that the results of this research may not be generalizable beyond the scope of this particular lecture style and/or the flight strip marking unit.

The generally accepted cut off level of probability for rejecting the null hypothesis is at 95% or $P=.05$ and the more stringent confidence interval is at 99% or $P=.01$. However, statistical evidence of this study support a confidence level of $P=.0001$. This level of probability leads this researcher to believe that there is only one chance in ten thousand that the results were due to sampling error. A summary of the analysis of variance results and probability factor is depicted in table 1.

**Table 1. Summary of Analysis of Variance**

<table>
<thead>
<tr>
<th>Source:</th>
<th>DF:</th>
<th>Sum Squares:</th>
<th>Mean Squares:</th>
<th>F-test:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1</td>
<td>2529.713</td>
<td>2529.713</td>
<td>27.79</td>
</tr>
<tr>
<td>Within Groups</td>
<td>23</td>
<td>2093.327</td>
<td>91.014</td>
<td>$P=.0001$</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>4623.04</td>
<td>192.626</td>
<td></td>
</tr>
</tbody>
</table>

For significance at $P=.01$ at d's of 1 and 23, an F ratio of 7.95 is required. This obtained F ratio of 27.79 obviously exceeds the required value for significance at $P=.01$. Therefore, on the basis of the F test, one must reject the null hypothesis, concluding that there is a significant difference between the two sample means, and that difference is not simply a result of sampling error. Accordingly, there exists a significant difference between the mean square of each group. Statistical analysis and a review of the literature suggests that these differences are attributable to the distinct and dissimilar modes of instruction.
As can be derived from the unit test raw scores in table 2, there is a significant difference between the means of the scores of both the control and experimental groups. It should also be noted that the spread of scores in the computer-assisted section was much more confined than the scores of the lecture class.

Table 2. Unit Test Raw Scores

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>93</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>87</td>
<td>100</td>
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<tr>
<td>4</td>
<td>84</td>
<td>100</td>
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<td>5</td>
<td>84</td>
<td>100</td>
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<td>6</td>
<td>81</td>
<td>96</td>
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<td>7</td>
<td>81</td>
<td>96</td>
</tr>
<tr>
<td>8</td>
<td>78</td>
<td>96</td>
</tr>
<tr>
<td>9</td>
<td>63</td>
<td>96</td>
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<td>10</td>
<td>60</td>
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<td>11</td>
<td>57</td>
<td>93</td>
</tr>
<tr>
<td>12</td>
<td>57</td>
<td>90</td>
</tr>
<tr>
<td>13</td>
<td>*</td>
<td>90</td>
</tr>
</tbody>
</table>

As seen in table 2, the post-test scores of the experimental group (computer-assisted section) were significantly higher across the board when compared to the scores attained by the control group (lecture-only section).

Conversely, the scores of the control group are on a much wider scale. Two of the lecture-only students scored 57% and only two students scored in the 90% range. In fact, all of the students in the experimental group scored 90% or higher; over a third of this group scoring 100%. The high scores of the CAI students are directly related to the systematic design of the instruction to train to mastery. These student scores are also
depicted in the bar graph in figure 4. It is graphically noted that the within group differences of the scores of individual students are well confined in the CAI section, whereas, in the lecture group there seems to be a wide disparity of achievement.

![Bar Graph of Student Raw Scores](image)

**Figure 4. Bar Graph of Student Raw Scores**

The control group had the same amount of instruction occurring at the same time of day as the experimental group and neither group was encouraged to study the material outside of class. Yet, the mean of the control group was significantly lower while the standard deviation was disparagingly high. The mean, standard deviation, and the standard error for both groups can be seen in the descriptive statistics in table 3.

**Table 3. Descriptive Statistics**

<table>
<thead>
<tr>
<th>Group</th>
<th>Count</th>
<th>Mean:</th>
<th>Std. Deviation:</th>
<th>Std. Error:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>12</td>
<td>76.25</td>
<td>13.26</td>
<td>3.828</td>
</tr>
<tr>
<td>Experimental</td>
<td>13</td>
<td>96.385</td>
<td>3.641</td>
<td>1.01</td>
</tr>
</tbody>
</table>
This researcher notes two possible explanations to interpret the 3.82 points of standard error between sample means that were observed in the results obtained in the lecture class. One way to account for this error is to acknowledge that students respond very differently to the lecture classroom. Marzano et al. (1988) found that many of the activities and interaction patterns in lecture classrooms do not actively contribute to the learning process for many individuals. However, students that are in command of various learning strategies respond very well to the lecture classroom, have adapted to it, don't mind learning in the lecture environment, and even excel when compared to their counterparts.

Marzano et al. (1988) also maintains that for learning to take place, the student must exert metacognitive control over the learning process. Many university students have difficulty implementing various metacognitive processes and learning strategies when faced with a specific learning objective. Yet, Collins and Brown (1989) identify the ability of knowing when to use one cognitive strategy over another as a critical element in any educational/training program. To exert metacognitive control in a learning situation, the student "must know what facts and concepts are necessary for the task; which strategies, heuristics, or procedures are appropriate (conditional knowledge); and how to apply the selected strategy, procedure, or heuristic" (Marzano et al., 1988, p. 14).

Not only do many students need to be more active in the teaching/learning process, but due to a lack of expertise in employing the correct learning strategy, many students have difficulty with the learning task altogether. These students often feel most comfortable when a proven learning strategy is provided as part of the information presentation, as it is with well designed CAI. When a learning strategy is not provided, as is often the case in the lecture classroom, many students do not internalize the information presented during the didactic tutelage. These learning style disparities put the students on
unequal footing and this reason, among others, can explain the wide range of scores for
the control group and the resulting the three points of standard error. The standard error
in the experimental group might have been kept to a minimum because a proven learning
strategy was incorporated as part of the CAI lesson. As can be concluded by the raw
scores of the computer-assisted section, most of the CAI students found this learning
strategy to be appropriate and quite effective.

Another way one may account for the standard error in the control group is the
student's unfamiliarity with the computer medium. However, it should be understood that
the students in both groups were upperclass men and women. As such, these students
were quite familiar with computer operations, having taken classes in word processing and
programming as part of their undergraduate coursework.

The unit test was administered to all students utilizing the computer. Both groups
raised few questions about typing and entering their results and it seemed that all felt very
comfortable taking the unit test on computer. In any case, given the magnitude of the
control group raw score deviations, this researcher contends that the raw score variations
cannot be due solely to the lecture-based subjects' lack of familiarity with the computer
medium. Rather, the standard error is more likely due to problems inherent with the
lecture classroom and this cannot be controlled.

It could be argued that the high scores achieved by the CAI group were
attributable to novelty of the computer medium or a Hawthorne effect. The probability
that the strong preference for computers in the present study was due primarily to novelty
of the computer medium seems unlikely because the upper-class students already had
much exposure with the use of microcomputers at the university level. The short duration
of this study and the fact that the students were not aware that they were part of an
experiment leads this researcher to conclude that a Hawthorne effect was also not a factor.
However, it is possible that the CAI students found it novel to be able to control their direction and progress throughout the learning process. The high scores of the computer-assisted section could be directly attributed to the interactive computer learning environment and valuable learning strategy incorporated therein. The literature clearly suggests that the student controlling the direction and speed of his or her learning process is more involved, motivated, interested, and more likely to be successful in accomplishing the learning objectives.

Spurious observations also noted that the students exhibited an intrinsic motivation to learn the subject matter on the computer. Many of the CAI students arrived early to class and accessed the lesson with genuine interest. When the students were asked to candidly disclose their impressions on the computer-aided instruction some students in the experimental section anonymously complied.

Subject 1. I like this type of learning. I learned the material and it was fun.
Subject 2. This was good. I liked being able to choose what I wanted to review.
Subject 3. This is a great way to learn. This program really worked for me.
Subject 4. This computerized instruction was enjoyable. I like the fact that the information is given much faster if you want to.
Subject 5. This was fun. I wish all my classes were taught this way.

These data indicate that CAI was the method of instruction that was more efficient in transmitting the desired knowledge to the student in the briefest period of time. The F-test and confidence level of .0001 strongly suggest that the learning and retention rates of students taught with the systematically designed and interactive computer-based instruction was significantly greater than those subjects that were taught by the didactic method.
Conclusions and Recommendations

It is very difficult to compare the lecture method of instruction with the computer-assisted instructional delivery as the two forms of instruction are so fundamentally different. It is enigmatic to routinely conclude that the same variables are being compared in both methods of instruction. In the lecture environment learning is controlled by the instructor, while the computer-based learning environment is primarily controlled by the student. In addition, the well designed CAI environment has an appropriate learning strategy built into the instruction. The lecture environment, however, often leaves the student to determine an appropriate learning strategy.

Normally, the professor that teaches by lecture is often unsure that 100% of the students are internalizing what is being introduced. Well designed and highly interactive computer-aided instruction, on the other hand, teaches to mastery; the student cannot progress to the next area until he/she has mastered the information in the previous section. The interactive tutorial regimes along with drill and practice sections and incremental audit testing, all serve to assure the students that they are correctly understanding the information and that they are in control of their own learning process. Additionally, feedback in the CAI classroom is immediate and frequent.

Well designed computer-based instruction is akin to the one-to-one student/teacher relationship. It is unfair to expect any university to instigate a cost-prohibitive one-on-one Socratic student/teacher dialogue. At this time, the computer is the only economical means to take advantage of this advantageous one-on-one teaching/learning scenario.
The results of this study do not suggest that the computer is more effective than the university professor. A single computer could never be expected to effectively instruct 25 students simultaneously; a task a lecture professor is expected to expertly accomplish on a daily basis.

However, it is obvious that students learn at different rates and it is inevitable that the instructor will progress too fast for some, while proceeding frustratingly slowly for others. It is very difficult for the didactic method of instruction to adequately account for individual student differences. One of the conclusions of this study is that CAI furnishes the student with the opportunity to control the pace and style of his/her learning process and it is possible that this student control stimulates an adaptable, effective learning experience for more of the students.

In addition, this researcher also concludes that high amounts of interactivity in the CAI lessons kept the interest levels of the students elevated. An interested student is not bored, is an effective learner, and remains more alert throughout the learning experience. The systematic approach to the design of the CAI instruction allowed the students to review what they needed at exactly the moment that the students needed that specific review, thereby minimizing student frustration. In addition, the drill and practice sequences enabled the students to take the material from short term memory and elaborate on it, developing automaticity as the information was recalled and reinforced, in and out of long term memory. It is recommended that further research be initiated to determine the most effective drill and practice regimes for various intellectual skills and cognitive strategies.

The lecture debacle is another area requiring further study. There is no universally recognized definition that characterizes the superior and inferior lecture style. In the flight strip marking unit, the lecture class was presented with the information necessary to
create, update, and interpret terminal flight strips. This information presentation could have been attended to in many ways.

Specifically, all lecture classrooms are not the same. Some professors incorporate drill and practice into the lecture format, further helping certain students internalize the information as the lecture progresses. Other lecture formats do not incorporate drill and practice sequences or quizzes during the classroom activities. Therefore, all lecture classes are not equal and it is unknown by this researcher which learning styles are best accommodated by the various lecture methods. Further research in the types of lecture and their effects on individual learning styles is recommended.

Some deficiencies that accompany the didactic method are very hard to rectify. University students admit that on occasion concepts presented in a university lecture can be incorrectly interpreted during the lecture and ingrained that way; this situation not being rectified until after the testing device is initiated (S. R. Hart, personal communication, October 11, 1992). However, an erroneous understanding of the material is much less likely to occur with the intense checks and balances that are incorporated in the systematically designed CAI experience. Furthermore, the same lecture taught to different classes can be very disparate. Whereas the computer instruction, unless reprogrammed, always presents the same information in the same manner. These are all possible explanations for the extreme within group variance of the lecture group raw scores and the confined spread of elevated scores that were found in the CAI class.

However, the computer also has many limitations that have been meticulously outlined in this research. CAI is not the answer for all learning domains. The flight strip marking unit contained the type of rote learning that was especially appropriate for this type of tutorial/drill and practice computer-based instruction. Instructional designers of different ATC special training areas must individually decide what instructional delivery
systems would be most propitious and these decisions must be made on a case-by-case basis.

It should be stressed that while the instructional benefit of the computer in this study was outstanding, the computer is not appropriate for every training situation. However, when deemed suitable, computer-based instruction must be systematically designed. The recipe for creating effective computer-based instruction includes a complex blend of the right ingredients. Subject matter experts, software and graphics consultants, and an instructional design team that is familiar with the strengths and weakness of CAI, are all necessary in the creation of effective and interactive educational software.

It should also be noted that with the proper training the university professor can, in many cases, encompass all these areas of expertise. The computer technology available today is superb and it usually lives up to its promise. So often, however, this technology outpaces our ability to use it (Foster, 1988).

On the whole, the results of this study support direct instruction with a computer program that exhibits a high degree of interactivity in rote learning applications for the ATC training environment. However, the results presented in this study indicate that the efficiency of CAI cannot be taken for granted. It is the systematic design of the instruction that makes the learning experience more meaningful and helps maximize the lesson's effectiveness. It is envisioned that there may be a promising future for CAI in many university educational applications. This researcher expects that this mode of instruction could effectively be employed in more areas of the air traffic control training regime to positively effect learning and achievement.

This study has been concerned with enhancing learning and retention rates of students in one specific area of ATC education, an expanded study including more of the units of ATC instruction is suggested. This researcher also submits that it would be
advantageous for universities to develop the means to stimulate interest in the
development of computer-based instruction in others areas of university coursework as
well. One of the goals of education is to transmit information to students in the most
motivating, stimulating, and effective way possible. Utilizing highly interactive CAI
clearly fulfills this objective.

A systematic design of instruction is the first step in the creation of valuable
educational software. It is encouraged, as part of this systematic process, that after the
original version is created and implemented the instructor revise any areas of the software
that need elaboration or modification. One of the strengths of CAI is the ability to
continually improve the instruction in an incremental manner thereby increasing its validity
and reliability.

Making the student an active part of the learning process is often difficult in the
university classroom. Stimulating, creative, interactive, and well designed instructional
software will not replace the professor, but it may be part of the solution toward making
the educational experience more personal, effective, and enjoyable.


APPENDIX A

RANDOM NUMBER GENERATOR PROGRAMMED IN "C"

FOR RANDOM SELECTION OF SUBJECTS
Random Selection of Subjects by Random Number Generator

/** This is a random number generator in C **/
/** It generates numbers 1-25 in two groups **/
/** Input to the program is a seed with any range**/

#include <stdlib.h>
define MAX 25

main(argc, argv)
int argc;
char *argv[];
{
    int seed, i, j, temp, flag;
    int rand_num[MAX];
    seed = atoi(argv[1]);
    i = 0; flag = 0;
    while ( i != MAX )
    {
        srand (seed+i+j);
        temp = (rand() % MAX) + 1;
        for (j=0; j<=i; j++)
        {
            if (temp == rand_num[j])
            {
                flag = 1;
                printf("Duplicate Found : Excluding %d
", temp);
            }
        }
        seed += j;
    }
    if (!flag)
    {
        rand_num[i] = temp;
        printf("Number found : %d\n", temp);
    }
i++;  
flag = 0;  
j++;  
}
printf("List 1\tList 2\n");
printf("-------\t-------\n");
for (i=0; i<=MAX-2; i+=2)
{
    printf("%6d\t%6d\n",rand_num[i], rand_num[i+1]);}
printf("%6d\n",rand_num[MAX-1]);
Subjects

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>93</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
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<tr>
<td>6</td>
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<td>96</td>
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<td>96</td>
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<tr>
<td>8</td>
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<td>96</td>
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<tr>
<td>9</td>
<td>63</td>
<td>96</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>96</td>
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<td>11</td>
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<td>93</td>
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<tr>
<td>12</td>
<td>57</td>
<td>90</td>
</tr>
<tr>
<td>13</td>
<td>*</td>
<td>90</td>
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</tbody>
</table>

**Descriptive Statistics**

<table>
<thead>
<tr>
<th>Group</th>
<th>Count</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>12</td>
<td>76.25</td>
<td>13.26</td>
<td>3.828</td>
</tr>
<tr>
<td>Experimental</td>
<td>13</td>
<td>96.385</td>
<td>3.641</td>
<td>1.01</td>
</tr>
</tbody>
</table>

**Summary of Analysis of Variance**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum Squares</th>
<th>Mean Squares</th>
<th>F-test:</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1</td>
<td>2529.713</td>
<td>2529.713</td>
<td>27.79</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Within Groups</td>
<td>23</td>
<td>2093.327</td>
<td>91.014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>4623.04</td>
<td>192.626</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C

INSTRUMENT: THE UNIT TEST ON FLIGHT STRIP MARKING
(VIEWS OF EACH COMPUTER FRAME)
Question #1

Enter the number that corresponds to the type of flight strip that is displayed below:

1 - Arrival flight strip
2 - Departure flight strip
3 - Overflight flight strip

<table>
<thead>
<tr>
<th>N34MT</th>
<th>P34/R</th>
<th>0224</th>
<th>EMB</th>
<th>EMB GCH V123 JAX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P1345</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>180</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

125.8

Question #2

Enter the number that corresponds to the type of flight strip displayed below:

1 - Arrival flight strip
2 - Departure flight strip
3 - Overflight flight strip

<table>
<thead>
<tr>
<th>NWA123</th>
<th>DC9/R</th>
<th>3021</th>
<th>1235</th>
<th>220 MLB V3 SAV V185 BEANS AGS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GCH</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GNZ</td>
<td></td>
</tr>
</tbody>
</table>

122.2
Question #3

Enter the number that corresponds to the type of flight strip displayed below:

1 - Arrival flight strip
2 - Departure flight strip
3 - Overflight flight strip

<table>
<thead>
<tr>
<th>QLH543</th>
<th>0987</th>
<th>RDL</th>
<th>340</th>
<th>H090</th>
<th>R</th>
<th>1235</th>
</tr>
</thead>
<tbody>
<tr>
<td>L007/R</td>
<td>LARRY</td>
<td>CHICO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>122.2</td>
</tr>
</tbody>
</table>

Question #4

On a departure strip, in which field is the transponder code marked?
Type the number of the field.
Question #5

On a departure strip, in which field is the route of flight information marked?
Type the number of the field.

Question #6

On an arrival strip, in which field is the coordination fix marked?
Type the number of the field.
Question #7

On an arrival strip, in which field is the entry fix marked?
Type the number of the correct field.

Question #8

On an arrival strip, in which field is the destination airport marked?
Type the number of the correct field.
Question #9

On an overflight strip, in which field is the altitude marked?
Type the number of the field.

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2A</td>
<td></td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Question #10

On an overflight strip, the estimated time over the entry fix is marked in which field?
Type the number of that field.

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2A</td>
<td></td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Question #11

On an overflight strip, in which field is the exit fix marked? Type the number of the field.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 10 | 11 | 12 |
| 13 | 14 | 15 |
| 16 | 17 | 18 |

Question #12

On an arrival strip, in which field is the approach clearance time marked? Type the number of the field.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 10 | 11 | 12 |
| 13 | 14 | 15 |
| 16 | 17 | 18 |
Question #13

On the terminal flight strip, in which field is the aircraft identification marked?
Type the correct field.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>2A</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>9A</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>2A</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>9A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>2A</td>
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<td></td>
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<td></td>
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<tr>
<td>4</td>
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<td>2A</td>
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<td></td>
<td></td>
<td></td>
<td>9A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Question #14

On the terminal flight strip, in which field is the handoff frequency marked?
Type the number of that field.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>2A</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>9A</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>2A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>2A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Question #15

On the terminal flight strip, in which field is the radio and radar contact marked? Type the number of the field.

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td></td>
<td>9A</td>
<td>13</td>
<td>14</td>
<td>15</td>
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<tr>
<td>4</td>
<td>7</td>
<td></td>
<td></td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
</tbody>
</table>

Question #16

On the departure strip, in which field is the proposed departure time marked? Type the number of the appropriate field.

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td></td>
<td>9A</td>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td></td>
<td></td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
</tbody>
</table>
Question #17

On the departure strip, in which field is the proposed cruising altitude marked?  
Type the number of the field.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>9A</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>7</td>
<td></td>
<td>8</td>
<td>9A</td>
<td></td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
</tbody>
</table>

Question #18

When you establish radar contact on QLH102, which field would you mark?  
Type the number of the field.

<table>
<thead>
<tr>
<th>QLH102</th>
<th>A320/R</th>
</tr>
</thead>
<tbody>
<tr>
<td>6561</td>
<td>P1715</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EMB</th>
<th>EMB GCH V23 GNZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>715</td>
<td></td>
</tr>
</tbody>
</table>

✓
Question #19

Which is the proper symbol used to denote radar contact?

Type the number that corresponds to the correct symbol.

1. /  2. R  3. ✓  4.  5. 

<table>
<thead>
<tr>
<th>QLH102</th>
<th>6561</th>
<th>EMB</th>
<th>EMB GCH V23 GNZ</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>A320/R</td>
<td>P1715</td>
<td>350</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Question #20

In which field would you mark an altitude restriction for this departing flight?
Type in the number that corresponds to the color of the correct area.

Type the number of your answer here:

Question #21

If you were to vector this aircraft on radar, where would you mark the issued headings?

Type the number of your answer here:
Question #22

If you have to hold this aircraft, where will you mark the holding instructions?

1. 2. 3. 4. 5. 6. 7. 8.

Type the number of your answer here:

Question #23

In which area would you update the altitude information?

1. 2. 3. 4. 5. 6. 7. 8.

Type the number of your answer here:
Question #24

When you hand this aircraft off to the next sector/facility, which area will be marked?

1.  
2.  
3.  
4.  
5.  
6.  
7.  
8.  

Type the number of your answer here: ✗

<table>
<thead>
<tr>
<th>N987KT</th>
<th>2066</th>
<th>RDL</th>
<th>RDL HARPO V23 LARRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA28/R</td>
<td>P1115</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Question #25

In which area are speed restrictions marked?

1.  
2.  
3.  
4.  
5.  
6.  
7.  
8.  

Type the number of your answer here: ✗

<table>
<thead>
<tr>
<th>N987KT</th>
<th>2066</th>
<th>RDL</th>
<th>RDL HARPO V23 LARRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA28/R</td>
<td>P1115</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Question #26

What is the handoff frequency of this flight?

<table>
<thead>
<tr>
<th>KAL009</th>
<th>6511</th>
<th>0605</th>
<th>310</th>
<th>TECCE EMR KEATN</th>
</tr>
</thead>
<tbody>
<tr>
<td>B747/R</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TECEE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KEATN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

121.1

Question #27

What is the proposed time over the entry fix for this aircraft?

<table>
<thead>
<tr>
<th>KAL009</th>
<th>6511</th>
<th>0605</th>
<th>310</th>
<th>TECCE EMR KEATN</th>
</tr>
</thead>
<tbody>
<tr>
<td>B747/R</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TECEE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KEATN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

121.1
**Question #28**

What is the proposed altitude for N123ER?
Enter (1, 2, 3, or 4).

1 - 60 feet  
2 - 600 feet  
3 - 6000 feet  
4 - FL 600

<table>
<thead>
<tr>
<th>N123ER</th>
<th>2356</th>
<th>RDL</th>
<th>RDL-EMR JERRY-CHA</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>C303/A</td>
<td>2356</td>
<td>RDL</td>
<td>RDL-EMR JERRY-CHA</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>P0730</td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td></td>
<td></td>
<td>R</td>
</tr>
</tbody>
</table>

**Question #29**

Is N123ER proceeding on its own navigation?
Enter (Yes or No)

<table>
<thead>
<tr>
<th>N123ER</th>
<th>2356</th>
<th>RDL</th>
<th>RDL-EMR JERRY-CHA</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>C303/A</td>
<td>2356</td>
<td>RDL</td>
<td>RDL-EMR JERRY-CHA</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>P0730</td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td></td>
<td></td>
<td>R</td>
</tr>
</tbody>
</table>
Question #30

What is the three letter identifier of the holding fix assigned to N23KP?

<table>
<thead>
<tr>
<th>N23KP</th>
<th>DC3/R</th>
<th>RDL</th>
<th>GCH</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2268</td>
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</tr>
<tr>
<td>SLK</td>
<td></td>
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<td>70</td>
<td></td>
</tr>
<tr>
<td>CHP</td>
<td></td>
<td></td>
<td></td>
<td></td>
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Question #31

At what time was the approach clearance issued to this aircraft?

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<th>DC3/R</th>
<th>RDL</th>
<th>GCH</th>
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121.3
Question #32

Has N39TR reported level at 7000 feet?
Enter (Yes or No).

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<th>90-70</th>
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Question #33

What is the three letter identifier for the destination airport?

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