SIMULATING USER EXPERIENCES IN COMPUTER-BASED MULTIMEDIA INSTRUCTION

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(ABSTRACT)

This research compared the effectiveness of three methods of instruction for two domains of learning. A text-based instructional system (control condition) was compared to a standard computer-based multimedia system (experimental treatment 2) and to a computer-based multimedia system that simulated a mock industrial setting (experimental treatment 3). Each condition was measured for its effectiveness in teaching verbal information skills (memorization) and intellectual (problem-solving) skills. The research design used was a three-by-two, mixed factors design with Method of Instruction as the between-subjects variable and Domain of Learning as the within-subjects variable. It was hypothesized that the multimedia treatment conditions would result in greater original learning among subjects than the control condition. It was further hypothesized that there would be an interaction between Method of Instruction and Domain of Learning, and also that the multimedia simulation condition would result in greater original learning among subjects than the standard multimedia condition. Thirty subjects of similar knowledge, skills, and abilities were selected to participate in the study. An experimental post-test was administered to subjects to measure their degree of original learning. The scores were recorded and an Analysis of Variance (ANOVA) was performed. This analysis showed a significant difference in the effectiveness of Method of Instruction on subjects' original learning, but no significant effects were found with the main effect of Domain of Learning or the interaction of Method of Instruction with Domain of Learning. A Newman-Keuls post-hoc test was performed to determine the locus of the main effect of Method of Instruction. This test showed that only the standard multimedia system (experimental treatment 2) resulted in significantly better original learning than the control condition. The effect of the multimedia simulation system (experimental treatment 3) was not shown to be statistically significant.

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INTRODUCTION

The modern academic environment is in the midst of an unprecedented evolution in instructional methods and technologies. Computer-based multimedia systems, which can provide astonishing visual and auditory effects, are now available to many educators and instructional designers. As with many new technologies, organizations and individuals are scurrying to jump on the multimedia bandwagon. All too often when multimedia systems are developed for training or instruction there is too great an emphasis on the technological attributes of the system and not enough thought or effort is given to the system's design to ensure that it will actually be effective.

For almost two years the Virginia Tech Department of Industrial and Systems Engineering (ISE) has had a great deal of interest in using the computer-based multimedia format to supplement classroom lectures and textbooks. ISE developers realized the awesome potential of multimedia, but also recognized that such systems cannot rely solely on their ability to display high-quality graphics, audio, and video. It was decided that a classroom topic would be chosen as the focus of a pilot multimedia effort to study the most effective ways to combine and present instruction in a computer-based multimedia format. The topic selected was Time Study Analysis, part of a junior-level ISE course entitled Work Measurement and Methods.

In the beginning, ISE developers were anxious to establish that multimedia was indeed a more effective method of instruction than traditional media (such as textbooks). Furthermore, once they had been introduced to the capabilities of multimedia technology, ISE developers realized that they could be very flexible and creative in their approach to the design of the Time Study Analysis instructional system. Thus, ISE developers decided to create multiple systems, using a different design approach for each, so they could examine which method(s) of multimedia system design showed the most promise.

The research project that resulted was a comparison of three methods of presenting instructional material. The first method presented the content in a hard-copy, text-based handout and served as the control condition for the study. The remaining two methods were multimedia systems of contrasting design approaches. The first multimedia system presented the content in a highly structured manner and incorporated combinations of digital video, audio, animation, graphics, and text where appropriate. The second multimedia system also presented highly organized information and took full advantage of multimedia technology, but went one step further by establishing a fictitious set of people, places, and events to simulate a typical industrial setting where time study analyses are often required. The results of each subject's instruction were compiled and analyzed to determine which, if any, of the three instructional conditions resulted in the greatest degree of learning.

1. BACKGROUND

1.1 Overview

The purpose of this study was to compare methods of individualized instruction to determine which, if any, resulted in the greatest degree of learning. Learning, though mysterious in some ways, has been very well researched. It can be described as an event that is made up of three basic components: the learner, the stimulus, and the response (Gagné, 1985).

The first element, the learner, refers simply to the person or individual. The individual's memory is a critical element of the learning event, and is the central component of the human information processing model. This model depicts the sequence of internal events that take place when an individual is presented with a stimulus (Wickens, 1992). The stimulus is the second element of the model, and it refers to the content and organization of the information that the learner is presented with. The last element, the response, refers to the actions that result from the stimulus (or stimuli) and their subsequent transformations (Gagné, 1985).

The nature of these three elements points to a clear strategy for designing instruction that should result in learning: if the nature of the learner, the information to be learned, and the appropriate ways to present that information are all understood, then a method of instruction can be developed that should result in the proper responses (which implies learning has occurred). This is certainly true for the purposes of this study. First, the nature of the learner must be thoroughly examined. Next, the nature of the information to be learned must be highly refined and organized. In addition, the proper ways to develop each of the proposed instructional systems (textual and computer-based interactive multimedia) must be ascertained. Finally, it must be determined through experimentation which of these methods of instruction results in the greatest degree of learning.

1.2 The Individual Learner

1.2.1 Human information processing. Human learning can be described as an internal *process* (Gagné, 1985). This process is commonly thought of as the human information-processing model, in which memory is the central component. Human memory is essentially comprised of two parts: working memory (or short-term memory), and long-term memory (Wickens, 1992). Working memory is where all new information is temporarily stored, and where some mental activity such as arithmetic or decision-making occurs. Long-term memory is a more permanent storehouse of information. Information that is temporarily stored in working memory can either be committed to long-term memory or lost (forgotten).

For learning to occur, information must enter working memory. Wickens (1992) described the way that memory handles informational stimuli as a three-step process. The first step, encoding, is the operation in which information is placed into working memory. The second step, storage, is the manner in which the information is encoded. It can be encoded as either spatial or verbal information (for working memory) or as procedural and declarative knowledge, and mental models (for long-term memory). The final step, retrieval, is the process of successfully getting information out of memory. By contrast, the failure to retrieve information defines *forgetting*. Forgetting can manifest itself as either a complete failure to remember information or as the incomplete or erroneous retrieval of information. Figure 1.1 shows a simple representation of the human memory functions.

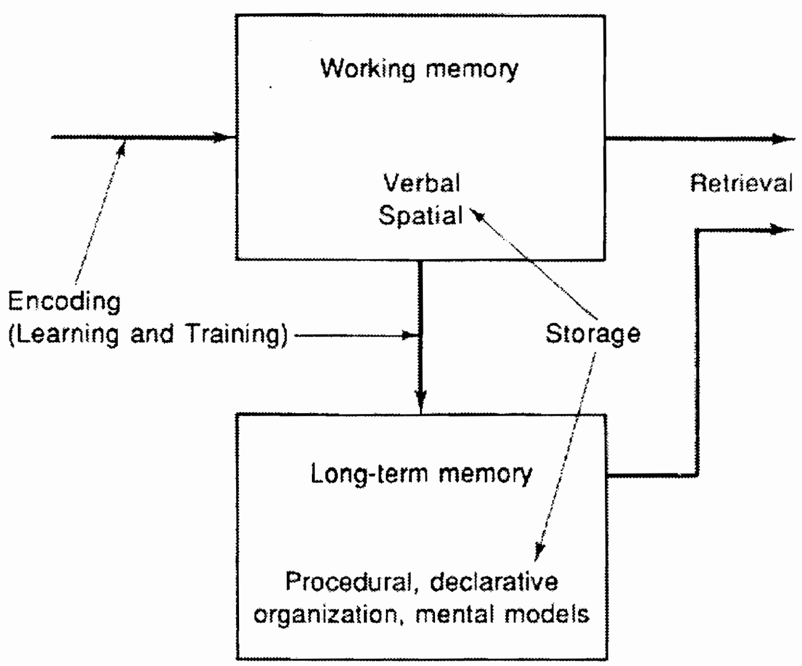

Figure 1.1: Representation of Basic Memory Functions (from Wickens, 1992)

1.2.2 Display modality and working memory code. As previously noted, the first step in the memory process is the encoding of information. Information is encoded into working memory in two ways: spatially and verbally. Spatial encoding represents information in a visual form, usually as analog images (Wickens, 1992). The visual nature of this form of encoding led Baddeley (1990) to describe spatial working memory as a "visual spatial scratchpad." Verbal encoding represents information in a phonetic format, usually as words and sounds (Wickens, 1992).

These two kinds of working memory seem to be somewhat independent and can be susceptible to interference from some kinds of concurrent activities (Baddeley, Grant, Wight, and Thompson, 1975). However, it has been argued by Posner (1978) that each of these works more cooperatively than competitively, and that both can be activated simultaneously by certain stimuli, such as pictures of common objects. At any rate, the dichotomy that exists between each of these kinds of working memory has implications for optimum display formats for information presentation.

In a model developed by Wickens, Sandry, and Vidulich (1983), an optimum match between modes of stimulus (format of information being received) and codes of working memory (format of information stored) was established. In this model there are four possible modes of stimulus: print, analog pictures, speech, and sound localization &

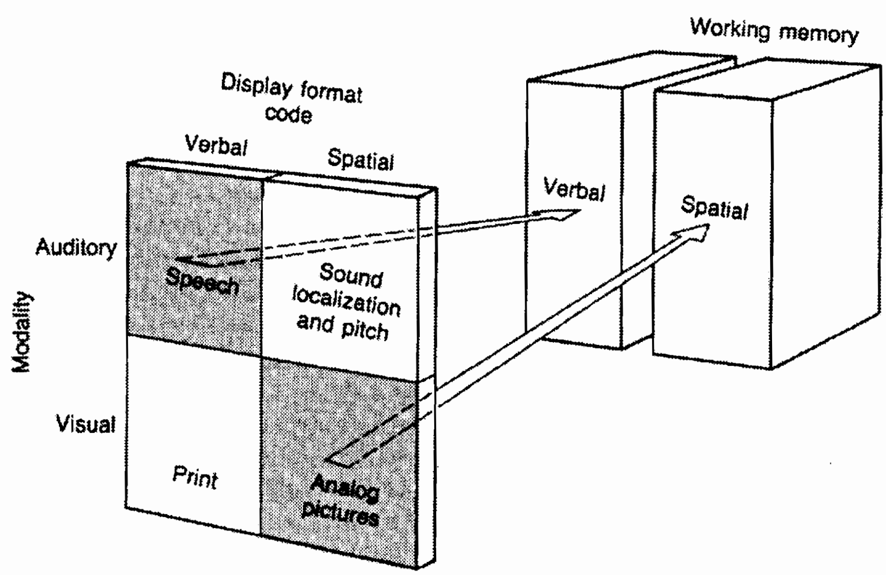

Figure 1.2: Display Modality and Working Memory Codes (from Wickens, 1992)

pitch. Figure 1.2 shows the relationship between modes of stimulus and codes of working memory. The combination of the shaded blocks and the connecting arrows represent the optimum combination of stimulus mode and working memory code for the given memory tasks.

Wickens (1992) stressed that there is a significant qualification concerning the auditory representation of verbal information when the message becomes very long. If the message is longer than four or five unrelated words then the auditory format is likely to result in a failure of memory. In this case, Wickens (1992) suggested that some means of prolonging the message is required. He stated that "...an optimal format would be one in which auditory delivery is 'echoed' by a more permanent printed record." This implies that auditory information is far more likely to be retained in memory when accompanied by a corresponding printed version of the message.

1.2.3 Factors affecting working memory retrieval. Working memory, where information is first stored, is limited by a rapid rate of decay or loss of availability of the information it contains (Wickens, 1992). In general, both the auditory and visual components of memory experience rapid decay. This, of course, results in greater difficulty in information retrieval, or "remembering." Among the factors affecting the probability of remembering information in working memory are time, interference, and capacity (Wickens, 1992).

Time demands have been shown to have a profound impact on the limits of working memory. Studies by Peterson and Peterson (1959) and Brown (1959) led to the development of what is known as the Brown-Peterson paradigm. Their studies tested the ability of subjects to recall small amounts of information (such as 1-letter, 3-letter, and 5-letter items) after varying intervals of time and without allowing the subjects to rehearse the information. Both studies found that retention of certain amounts of information fell to nearly zero after only 20 seconds when rehearsal was prevented.

Interference also has a significant impact on working memory. In this case, interference refers to other mental activities that must be performed while information is being stored in working memory for retrieval at some time in the future. This kind of interference can be proactive (in which the mental activity that disrupts the memory function occurs prior to encoding of the information) or retroactive (in which the mental activity that disrupts the memory function occurs after the information has already been encoded).

Time and attention alone do not define the limits of working memory, however. The Brown-Peterson paradigm also shows that there is a limit on the amount of information at which retention fails even immediately after presentation. This limit was elegantly summarized by Miller (1956) in his paper "The magical number seven plus or minus two." He asserted that the capacity of working memory is roughly between five and nine items when full attention is allocated.

The concept of an "item" in working memory is somewhat vague. In the studies by Brown and the Petersons an "item" was represented by a single character. But Miller (1956) proposed the concept of a "chunk" of information. He contended that a chunk of information can be a letter, word, or group of words, and that the capacity of working memory is 7 ± 2 chunks of information. Chunks can be more than just a few words; if a series of words or characters is related or sequenced in some way, retention will be easier. Wickens (1992) offers an example: the statement "London is the largest city in England", although it contains seven words, is a single chunk because the words are related to form one distinct piece of information.

1.2.4 Domains of learning. The functional intricacies of human memory are just one piece of the learning puzzle. Up to this point, the term "information" has meant any generic knowledge that is to be learned. But information, of course, is extremely diverse. In order to properly design an effective instructional system, the nature of the information to be learned must be clarified. Gagné (1985) observed that there are different and distinct categories of learned human capabilities in educational settings and in everyday life, which he called "domains of learning." Following this concept, Dick and Carey (1990) proposed four domains of learning: (1) verbal information skills, (2) intellectual skills, (3) psychomotor skills, and (4) behavioral attitudes. The material learned by subjects in this study fell under two of these domains: verbal information skills and intellectual skills.

Verbal information is a fact or facts that a person may learn to state or tell by using speech, writing, typing, or drawing a picture (Gagné, 1985). Dick and Carey (1990) described verbal information skills by saying "...there is no symbolic manipulation--no problem solving or rule applying. In essence, verbal information goals require the learner to provide specific responses to relatively specific stimuli." Some examples of verbal information skills are: listing all the state capitals, naming the parts of a simple machine, or stating Newton's three laws of motion.

Intellectual skills can be briefly described as problem-solving skills (Dick and Carey, 1990). The learner is required to manipulate symbolic information and use previously acquired knowledge and information to solve a problem with previously unencountered information or examples. Some examples of intellectual skills are: being able to balance a checkbook, being able to classify a group of animals by their genus and species, or being able to tell if a sequence of words contains any misspellings.

1.3 The Systematic Approach to Instruction

1.3.1 Overview. It may seem that the processes of learning and instruction are strongly related. But would-be instructors must beware, since learning can occur without instruction, and instruction can certainly occur without learning. Indeed, learning describes the various ways that information can be committed to memory, while instruction refers to specific methods used by instructors to maximize the efficiency of learning (Wickens, 1992). The process of instruction (not learning) can be viewed as a system (Dick and Carey, 1990) and the most widely-accepted method of developing instruction is a systematic approach to its design, outlined by Goldstein (1993) and by Dick and Carey (1990).

The model for the systems approach to training (SAT) is the result of the efforts of numerous researchers over many years. But, as Dick and Carey (1990) pointed out, there is no single correct approach to instruction. Instead, there are many approaches that may be called "systems" approaches, but they each share common elements. Dick and Carey (1990) presented the model as a three-phase process, which is comprised of (1) the specification of training requirements, (2) the development of training content, and (3) the evaluation of training effectiveness. Figure 1.3 summarizes the relationship between these three phases, along with their components.

1.3.2 Determination of Instructional Requirements. It is evident from figure 1.3 that the first step in the SAT is the determination of training needs so that training objectives can be formulated. Dick and Carey (1990) proposed a host of techniques for data collection to identify training needs. However, the focus of this study was not on needs assessment strategies or any other part of the first phase of SAT. Instead, it was on the comparison of two multimedia training programs with a control condition. This control condition was of a textual format adapted from an existing textbook that is currently used to teach the instructional material. Therefore, training objectives were developed using the content of this textbook, not through data collection.

Training requirements are set forth in the form of statements of behavioral objectives (Goldstein, 1993, and Dick and Carey, 1990). The development of behavioral objectives served as the foundation for the subsequent steps in the SAT process. According to Dick and Carey (1990), these behavioral objectives are single sentences with

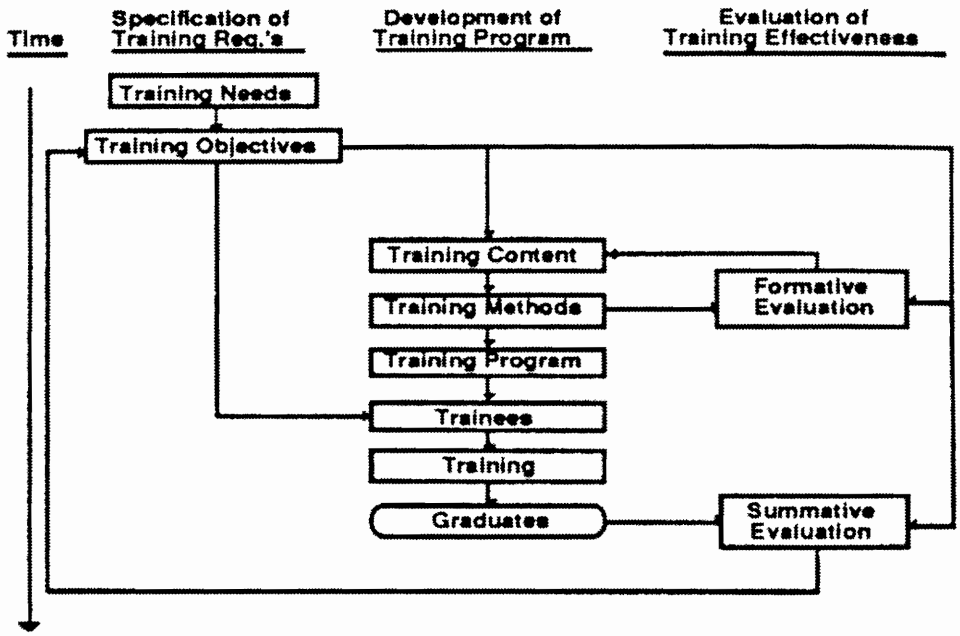

Figure 1.3: Components of a Systems Approach to Training

three basic components: (1) a description of the skill or behavior to be trained, (2) a statement of the conditions of performance, and (3) a clear definition of the acceptable level of trainee performance.

The third element of the behavioral objectives, in which acceptable levels of trainee performance are defined, required special attention. Dick and Carey (1990) noted that trainee performance is to be judged through the use of some form of testing. As previously discussed, this study contained instructional content that was both verbal information and intellectual skills. There were many intellectual and verbal information tasks that have only one correct response. In these cases Dick and Carey (1990) stressed that these correct responses are the criteria for acceptable performance. They also emphasized that specifying the number of times learners are to perform the task (such as "two out of three times" or "correct 80 percent of the time") *does not* indicate the objective criterion, but instead indicates required levels for *mastery*.

There are also many forms of verbal information and intellectual tasks in which a variety of responses can be considered correct. In these cases Dick and Carey (1990) proposed that "The criteria for such objectives should specify any information or features that must be present in a response for it to be considered accurate enough. For complex responses, a checklist of response features may be necessary to indicate the criteria for judging the acceptability of a response."

1.3.3 Development of performance criteria. Each behavioral objective should contain a statement of the acceptable level of trainee performance. These performance specifications can then be used as the basis for developing a system of evaluation through testing. Dick and Carey (1990) noted that a "fair and equitable evaluation system" is one that tests for the behaviors outlined in the behavioral objectives. They also pointed out that this kind of system offers two important advantages: (1) that student's learning can be monitored, and (2) that the effectiveness of the instruction can be closely examined. The second advantage is of particular relevance to this study, since different instructional methods were compared. Criterion-based testing can indicate to the instructional designer which segments of the instruction are effective and which need improvement (Dick and Carey, 1990).

There are essentially three kinds of criterion-based tests: pre-tests, post-tests, and embedded tests (Dick and Carey, 1990). Each of these tests are intended to be used during the design process so that the instructional system can be iteratively revised and improved. Pre-tests clearly have benefits, but they are not always required. Dick and Carey (1990) noted that if there are no significant entry behaviors identified, then a pre-test is not needed. They also state that "If you are teaching a topic that you know is new to your target population, and if their performance on a pre-test would only be the result of random guessing, it is probably not advisable to have a pre-test." Embedded tests, according to Dick and Carey (1990) are essentially practice items that offer no feedback. Instead, they are only for the benefit of the instructional designer because they show whether learners are able to perform a task or answer a question immediately after the material is taught. Dick and Carey (1990) also stressed that embedded test items are used almost exclusively with intellectual skills because "the designer should be able to use an unencountered instance of the application of the skill." Post-tests should be comprehensive and measure all stated performance objectives.

1.4 Development of the Instructional System

1.4.1 Pre-instructional activities. There are a few things instructors should do with learners before administering instruction. Specifically, the learner should be informed of the prerequisite skills required for the instructional program and of the objectives of the instructional system. According to Dick and Carey (1990), learners will benefit more from the instruction when they are aware of the special knowledge and/or skills required (if any) to undertake the instructional program. This can be done either through pre-testing or by simply providing learners with a brief description. It is also important that learners be informed of exactly what knowledge and/or skills they are to derive from the instruction (Gagné, 1985, and Dick and Carey 1990). Dick and Carey explained the reason for this through an example: often when reading a textbook or listening to a lecture, students wonder how much they should be committing to memory. Informing students of the objectives of the instruction should alleviate this confusion.

1.4.2 Learner motivation. During the administration of instruction, one factor that has a very significant impact on the degree of learning that occurs is the learner's motivation (Dick and Carey, 1990). According to Mitchell (1982), motivation is comprised of three psychological processes: arousal, direction, and persistence. Arousal and persistence are associated with the time and effort a learner invests in the instruction, while direction refers to the actual behaviors that the time and effort are invested in. Dick and Carey (1990) acknowledged that often a major shortcoming of instructional systems is their lack of interest and appeal to the learner. Numerous researchers, including Noe (1986) and Keller and Koop (1987), have formulated models to identify the factors that must be addressed so that an instructional system is found to be motivating by learners. Keller and Koop (1987) proposed the Attention, Relevance, Confidence, and Satisfaction model (ARCS). In other words, these four factors were the ones they identified as the four aspects of instruction that must be carefully considered in order to motivate learners.

Clearly attention is required for learning to occur. According to Keller and Koop, initial attention can be gained by "using emotional or personal information, asking questions, creating mental challenges, or perhaps the best method of all, using human interest examples." These forms of motivational techniques clearly have strong implications for the potential of multimedia forms of presentation.

Keller and Koop also established the issues of relevance and confidence as having a significant effect on learner motivation. Relevance is another key to gaining and holding learner attention. Learner confidence, however, can cause problems; underconfident learners will probably not be able to master the objectives of the instruction, while overconfident learners will likely be highly inattentive, feeling that they already "know it all."

Satisfaction, the fourth element of the Keller and Koop motivational model, can take more than one form. There is the subjective satisfaction of the learning experience, and the heightened self-esteem that comes with mastering a new skill. As with learner attention, the element of satisfaction would seem to benefit greatly from the proper forms of multimedia presentation.

1.4.3 Media selection. Selecting media for instruction is simply a means of determining the optimal combinations of things or systems used to deliver instructional stimuli to the learner (Gagné, 1985). Often, though, instructional media are selected based on organizational or logistical constraints, or the decision to use a certain medium is made at the beginning of the design process (Dick and Carey, 1990). There are models that outline desirable media choices for delivering various kinds of instruction, which implies, of course, that certain media are known to outperform certain other media for specified instructional situations. This, like the issue of learner motivation, has profound implications for the results of this study.

In 1983, Reiser and Gagné reviewed literature on the use of media in instruction and devised a model for assisting instructional developers in selecting media. The model is arranged as a flowchart, in which the developer moves through the chart, from the top, answering questions about the nature of the material to be taught until the "candidate media" are narrowed to a list of possible choices that would be appropriate (Reiser and Gagné, 1983). Figure 1.4 shows a portion of the actual diagram.

Note that the diagram lists a variety of media choices. Many of these were not considered in the design of the three instructional conditions used in this study since they cannot be presented by either printed material or computer-based multimedia instruction. Furthermore, upon careful examination it is evident that the model does not always specify clearly enough which media to choose. In some cases the model suggests a "computer" as the desired instructional medium. Clearly, this was inadequate for the purposes of this study, since it does not specify the media choices that the computer can provide. In these cases the findings of Wickens (1992) concerning display modality and working memory code can be enlisted to aid in selecting appropriate forms of instructional presentation.

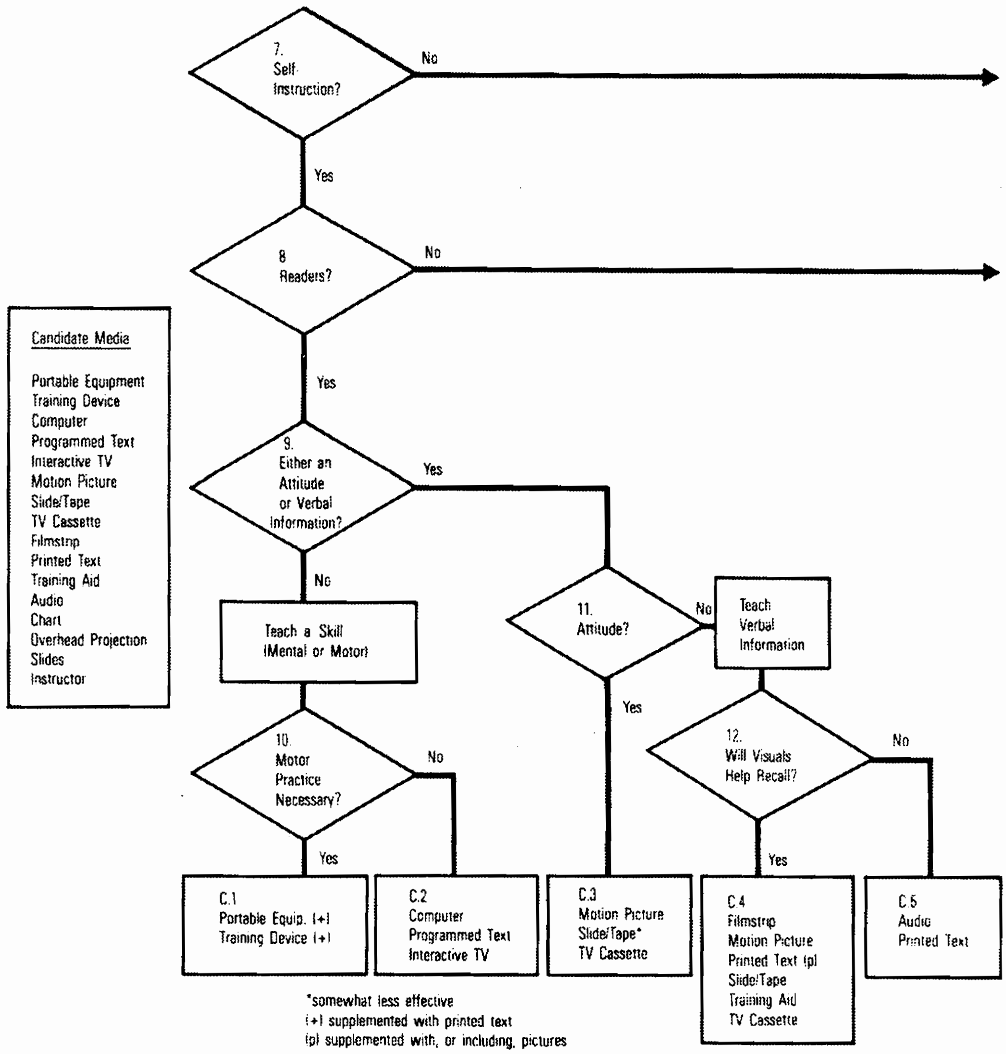

Figure 1.4: Partial representation of model for media selection in instruction (from Reiser and Gagné, 1983)

There are other considerations when selecting media for instruction. These include availability, flexibility, and cost-effectiveness (Dick and Carey, 1990). Availability will determine the actual list of candidate media that may be used in designing each of the three instructional conditions. This list will have only two overall formats to choose from:

printed material and computer-based multimedia. Certain specific media formats were also provided within each of these overall formats. The printed material format provided printed text , diagrams, and charts. The computer-based multimedia format provided printed text, still photographs, two-and-three dimensional animations, digital audio, and digital video. The issues of flexibility and cost-effectiveness were not relevant for the purposes of this study.

1.4.4 Interactive multimedia (IM) systems. Textbooks, which are common forms of printed instruction, offer highly organized and structured information and usually present that information with text and pictures. Because of this simple format, textbooks have persisted as the most popular form of information storage and presentation for over 700 years, from the first medieval universities to the modern college classrooms of today (Friedlander, 1989). However, far less is known about the intricacies and effectiveness of interactive multimedia (IM) systems. They have recently become popular for several reasons: they offer information presentation in media formats that textbooks cannot, they can provide self-contained, individualized instruction that classroom lectures cannot, and learners are often attracted by the novelty of their technological capabilities. Unfortunately, however, only a small collection of research literature exists, some of it conflicting, concerning the use of IM systems as instructional devices.

1.4.5 Basic components of IM systems. The appearance and function (or "look and feel") of an IM system depends largely on the developer and can vary greatly from one system to the next. However, there are certain components that are common to most systems. Modern IM systems are capable of presenting information in several different formats. Also, these systems must provide users with control over system navigation and the content they will see. Finally, the instruments for user navigation and review of system content, and the sections that will display the content, must be arranged and reside on the computer screen together.

There are five basic formats of media presentation offered by the IM system: text, graphics, animations, audio, and video. Text can be presented in a variety of fonts and colors, and is easily handled by IM programs and easily displayed by computer screens. Audio also presents few problems. All kinds of sounds, from short clips to lengthy musical passages and human speech, can be "captured" (recorded and digitized by the computer).

Computer graphics usually take the form of images created using special software or images that are scanned and digitized. Scanned images often contain a large amount of color information and can sometimes be displayed by the computer screen inaccurately. The problem is one of "color depth." Standard computer screens can only display an image at a resolution of 72 pixels per inch, whereas photographs or other images are printed at a much higher resolution. One way to minimize the effects of this often large discrepancy is to maximize the amount of color information the computer screen can display ("color depth"). Capturing video, scanning images, and developing animations at a 32-bit color depth (meaning a possibility of approximately 16.7 million different colors per individual pixel) helps reduce the loss of perceived image quality caused by the computer screen's limited display resolution.

Animations are somewhat tricky and, depending on their length and complexity, can often result in enormous file sizes. Computer-based video presents many of the same problems. The only difference between computer-based animations and computer-based video is that video is captured (in much the same way audio is captured), whereas animations are usually computer-generated (created directly within the computer environment). Obstacles often encountered when developing high-quality animations and video segments are perceived image quality and perceived smoothness of motion. As with scanned images, adjusting color depth can maximize the perceived quality of video and animation images. The obstacle of perceived smoothness of motion can be overcome through the use of small window sizes and/or through the use of frame rates slower than the standard analog video frame rate of 30 frames per second.

There are common devices used to give the user control of the multimedia environment. User navigation of the content of a system can be accomplished with pull-down or pop-up menus, but the most common choice is graphical "buttons" on the screen (Milheim and Lavix, 1992). These buttons are usually actuated using a mouse, but touch-screens are an alternative. Sections of screens that contain content information, regardless of media format, are most commonly graphical boxes or "windows" that serve to highlight their content or to separate their content from other items on the screen.

1.4.6 Guidelines for IM design The main function of each screen in an IM system is to direct learner attention toward its content information (Hannafin and Hooper, 1989) while providing instruments for user control and maintaining user interest in the system content. Though this sounds like a tall order, it can be accomplished with the use of text and graphics, proper screen layout, and appropriate user control devices. The following is a summary of some basic guidelines for IM design.

Although digital media such as video and audio are usually the most prominent features of an IM system, text should also be used in conjunction with these other media. General rules for using text in IM systems have been compiled by Hazen (1985), Garner (1990), and Wickens (1992). They suggest:

- group related segments of text and separate them from other textual information
- use varying type styles and sizes to place emphasis and add variety
- use left justification since spaces can interrupt eye movement and slow down reading speed
- organize text segments starting from the top left of the screen (for Western cultures)
- use text to reinforce transient information presented simultaneously in an auditory format

Computer graphics are an integral part of any IM system. Guidelines for using graphics have been compiled by Garner (1990), Rovick (1985), Hazen (1985), and Hannafin and Hooper (1989). They suggest:

- use graphical images to balance text that relates to or will accompany them
- use graphical images to illustrate an effect, capture and focus attention, and emphasize a relationship
- be acutely aware of image fidelity; do not show a poor-quality image for a demonstration of delicate surgery, for example

Color can be used effectively to engage user attention. Some simple guidelines for the use of color in IM systems have been established (Hannafin and Hooper, 1989), which include:

- use the brightest colors for the most important information
- use a neutral color (such as a gray tone) for a background since it recedes optically
- use colors that will provide enough contrast between background color(s) and foreground text or other information
- use commonly accepted colors for certain actions or prompts (such as red for stop or green for proceed)

On-screen user control devices must be easily understood and operated, particularly for novice or uninitiated learners. The control devices required by a system obviously vary greatly depending on the developer and the nature of the information being presented, but some devices, such as "next screen", "previous screen", "help", and "quit", are common most IM systems. Garner (1990) stressed that buttons should be placed consistently on the screen and must provide some form of visual feedback to the user when actuated. Garner also suggests locating these devices toward the bottom of the screen so that central screen space can be dedicated to content information.

These simple guidelines for interface design and layout are just one tool used in the overall design process. Before developers arrive at this stage they must have determined the fundamental instructional approach they wish to use and the overall structure and organization of content information within their systems.

1.4.7 Designing the IM system. Developing an IM system that showcases visual and auditory information presentation is fairly simple. Developing an IM system for the purposes of training or instruction, however, requires careful planning. The digital technology available is improving so rapidly in its breadth and quality that frequently there are whole ranges of possibilities available to the instructional multimedia developer. These new advancements offer many advantages over traditional forms of instruction, but there are important disadvantages as well.

Conklin (1987) summarized the advantages and disadvantages of using IM. Advantages include facilitating individual structuring of links and nodes of information, creating and tracing references, and pursuing multiple lines of inquiry practically simultaneously. Disadvantages include navigation disorientation and information or sensory overload. Hammond (1989) also stressed that learner commitment to the system content is an important problem.

Heller (1990) proposed that "...it is the disadvantages that are more informative to the educator as he or she goes about designing [IM]." Her assertion, that focusing on the potential pitfalls of IM instruction are more important to the developer, implies that the use of IM is obviously better as long as the pitfalls are avoided. In fact, the use of digital media alone does not guarantee that learners will derive greater benefit from the system. Nelson and Joyner (1990) showed that multimedia systems are not necessarily effective forms of information presentation. Their study was a comparison of a traditional, linear presentation of information and the same information presented within a multimedia system. The study resulted in significantly better recall of ideas by learners who viewed the information in the traditional, linear format. Clearly, IM systems must be very carefully designed and developed to ensure any instructional benefit.

Although the disadvantages of IM should not be the only considerations when developing IM instruction, it is easy to see why they are so important. Disorientation refers to not knowing where you are in the system and/or not knowing how to get somewhere you'd like to be (Conklin, 1987). Also, it is not uncommon for the developer, in an effort to use all of the available technology, to create a system with a barrage of visual and auditory displays. These obstacles, however, can be overcome with careful design and development.

The disorientation phenomena becomes more likely to occur and more likely to be severe as the size of the system and the amount of information it contains increases. Within this phenomena is the difficulty of knowing the size or extent of the system confronting the learner (Conklin, 1987). Conklin proposed a solution to this disorientation problem in the form of graphical, map-like images called "browsers." This name might be misleading; these graphical devices themselves do not browse, but rather allow the learner to browse through the content of the system accompanied by a graphical representation of where they are within the system.

As the extent of the material and the complexity of the system become even larger, however, these browsers may become more difficult to use. Hammond (1989) suggested that browsing, by its very nature, is informal, and often causes the user to grossly overestimate the percentage of the system's content he or she has already seen. Marchionini and Schneiderman (1988) reported that novice users usually browsed by following links*they* perceived to be important, rather than following a concise, structured strategy. Also, in a study by Jones (1989), participants who utilized a multimedia database by browsing revealed significant differences in recall of incidental information.

The second major problem with IM systems is the issue of cognitive overload. Again, browsers may be a solution to this problem by allowing users to control the amount of information they are exposed to. This way they do not have to confront any nodes in a deliberate review of their content. Learning will likely not occur if the learner's attention is divided among too many sources of information all at once. However, as Gagné (1985) pointed out, it is important to induce and maintain learner interest and motivation, and the visual and auditory capabilities of IM can accomplish this. Thus, the IM developer must find the happy medium between cognitive overload and engaging, motivating systems.

The issue of learner commitment should not be overlooked. The problem lies in users not knowing what information will be presented when a certain item on the screen is selected (or that the item can be selected at all). Raskin (1987) described a particular example of this in which a user was presented with the graphic image of a butterfly leg and was not sure if selecting the leg would supply any information or what information would be supplied. Thus, the user was not compelled to stay with the system to explore all the content it offered.

1.4.8 Contrasting IM design approaches. Issues of information structure, organization, and interface layout and design have already been discussed. There still remains, however, the issue of the design of the instruction, and, in particular, the corresponding approach to the development of the IM instructional system.

There are numerous ways to design and develop an IM system. Although the nature of a multimedia system depends greatly on its developer, Heller (1990) believes that all systems tend to reflect characteristics of one of two basic approaches: *knowledge presentation* and *knowledge construction.* Knowledge presentation systems contain information that has been associatively linked by the developer, so there are few (if any) attempts to provide the learner with any instruction. Knowledge construction systems support learners in direct interaction with information, allowing them to interact in context-rich simulations to construct personalized knowledge through "experiences."

Knowledge presentation forms of multimedia systems are very common. They offer information in a format (that the developer has chosen) that allows the user to browse freely through the information they contain. Usually the emphasis is not on a well-structured base of information, but instead on the examples of multimedia technology they contain, such as digital video segments for the user to watch. It is not sufficient to simply present information on a computer screen, even in multiple presentation forms (animation, video, etc.) and assume that the information will be adequately and accurately transferred to the knowledge base of the learner. However, using multimedia systems to provide learners with interactive activities and experiences shows promise for becoming an effective instructional approach.

The knowledge construction approach to multimedia system design is radically different. This approach is based on the idea that users should construct knowledge through activities and experiences. Bransford, Sherwood, Hasselbring, Kinzer, and Williams (1990) have argued that information transfer and use of knowledge for problem-solving would be facilitated by multimedia systems that emphasize "authentic experiences."

One key to this constructivist environment is the level of interactivity offered by the system. A contextualized computer environment (CCE) is one that utilizes pictures, sound, animation, and motion video to illustrate key ideas or even stories that will actively engage the learner (Heller, 1990). A CCE lends itself well to a constructivist system. One example of this is seen in a system that was designed by Nelson, Bueno, and Mohammed-Yusof (1991) to teach Spanish. The system's main goal is to provide an electronic setting for receiving comprehensible input in spoken and written forms through simulated "visits" to the Spanish city of Salamanca. During the visits, the learner meets two Spanish children and engages in a variety of activities that require listening to recordings of spoken Spanish, reading captions of instructions in the language, and responding or selecting within simulated pre-communicative practice activities. In addition, several instructional activities are incorporated into the CCE, including sentence completion, and listening and demonstrating understanding. Preliminary results indicate that the system is a valuable addition to the traditional foreign language classroom.

1.4.9 Instructional simulations. There is a recurring theme within the preceding collection of research on multimedia design approaches. Several of these investigations have suggested that the learning process can be enhanced through learner "experiences" which would indicate that some form of simulation might prove to be effective in the context of a multimedia instructional system. The objective of an instructional simulation is to create psychological fidelity through physical fidelity (Goldstein, 1993). This means that the behavioral processes needed to learn the task are recreated in the training tasks. One of the main reasons simulations are used is that the instructor has control over the instructional environment. Important factors of the instruction can be stressed while unimportant factors can be de-emphasized. Also, simulations provide the ability to expand, compress, or repeat time depending on the needs of the learner (Goldstein, 1993).

1.4.10 Business games. Simulations can take many different forms and can be used for many different instructional purposes. Probably the best-known type of simulation is used to teach skills development, such as in an aircraft simulator. But there have also been simulations developed for teaching a variety of other skills. Studies have been done which use simulation as a tool for examining information processing (Schroder, Driver, and Streufert, 1967), international relations (Guetzkow, 1971), police communications and stress (Drabek, 1969), and military decision-making (Olmstead, Cleary, Lackey, and Salter, 1973).

One particular simulation technique is called Business Games. Business Games are simulations that are typically used to teach or enhance business management skills (Goldstein, 1993). Dill, Jackson, and Sweeney (1961) described this kind of simulation by stating "A business game is a contrived situation which embeds players in a simulated business environment where they must make management-type decisions..."

One of the most carefully developed business game simulations, known as Looking Glass, Inc., was created and documented by McCall and Lombardo (1982). Like many business games, its purpose was to teach management skills. Looking Glass was developed to simulate a fictitious company burdened with typical industrial problems that required the attention of management. Participants were placed into an office-like setting complete with desks, phones, and an inter-office memo system. The simulation lasted six hours and was intended to be a typical day in the life of the company. It began with players arriving at work, going to their desks, and finding a basket filled with memos detailing problems within the company that needed to be addressed.

Clearly, this type of simulation is only indirectly applicable to the focus of this research. Business games have traditionally been a method of training for complex management skills, not simpler verbal information or intellectual skills. Also, the degree of physical fidelity is typically higher; participants actually sit at desks, converse on real telephones, or whatever else the simulation calls for, rather than participating less directly by having those elements recreated on a computer screen. However, it has already been shown that computer-based multimedia systems have great instructional potential when they create authentic user experiences. Simulations such as Looking Glass, Inc. provide a rough template for designing an environment that involves the learner in a make-believe sequence of events where a variety of knowledge, skills, and abilities can be learned.

1.5 Evaluation of the Instructional System

1.5.1 Rationale. The third and final phase of the SAT is to conduct an evaluation of the instructional system, which is comprised of a formative evaluation and a summative evaluation (Goldstein, 1993, and Dick and Carey, 1990). The formative evaluation is an iterative process, the purpose of which is to revise and improve the instructional system before it is actually used for teaching. The purpose of the summative evaluation is to determine the effectiveness of the overall finished product, which is consistent with the purposes of this study. Therefore, no formative evaluation will be performed; only a summative evaluation will be developed and conducted to determine the effectiveness of each training condition. According to Goldstein (1993), there are three determinations the instructional developer must make in evaluating training treatments: (1) whether a real change in learners' knowledge and abilities has occurred, (2) whether these changes are attributable to the instructional system, and (3) whether these changes are likely to occur again with other groups of learners.

1.5.2 Development of testing. The behavioral objectives should guide the writing of test items; a well-written test item should match the behavior and the conditions specified by the objective(s) and provide learners with the opportunity to meet the acceptable level of performance (Dick and Carey, 1990). Specifically, the instructional designer should use the learning task or verb stated in the objective to guide the format of the test item. There are certain formats for presenting learners with questions that are better than others (based on these learning tasks and verbs). Figure 1.5 summarizes the position of Dick and Carey on which format(s) of test items should be used with which tasks or verbs. The chart indicates that certain types of behavior can often be tested more than one way. However, some formats are still less desirable than some others. As Dick and Carey (1990) revealed, multiple choice and true/false formats are sometimes difficult to design without making them misleading, and they also provide learners with the possibility of guessing the correct response when, in fact, they do not know the right answer. Another consideration is the amount or number of test items that learners must respond to in order to completely display the knowledge or skill that is being taught. According to Dick and Carey (1990), assessing intellectual skills usually requires three or more opportunities to demonstrate the skill, while verbal information usually only requires one opportunity since there is usually only one correct response.

The sequencing of test items is another important consideration. According to Dick and Carey (1990) the traditional method of grouping test items is to cluster them based on item format (i.e. all multiple choice together, all essay together, etc.). They point out that, although this makes for an attractive and seemingly well-organized test, the content can be widely varied across groups of questions. This creates extra work for the instructor (who is assumed to also be the grader). Dick and Carey (1990) suggested that a superior method of sequencing test items is to group items of like content and objective regardless of presentation format.

It is also important to note that there are different components of learning. Goldstein (1993) listed three learning components: 1) original learning, 2) transfer of training, and 3) retention. Original learning refers to the knowledge and/or skills the learner can exhibit at the completion of instruction. Transfer refers to the degree to which knowledge and/or skills learned in training will "transfer" to the actual environment (such as the transfer of pilot skills from a flight simulator to an actual aircraft). Retention refers

	Types of Test Items						
Type of Behavior Stated in Objective	Essay	Fill-in-the-Blank	Completion	Multiple-Choice	Matching	Product Instructions	Live Performance Instructions
State	X	X	X				
Identify		X	X	X	X		
Discuss	X		X				
Define	X	X	X				
Select				X	X		
Discriminate				X	X		
Solve	X	X	X	X		X	
Develop	X		X			X	
Locate	X	X	X	X	X	X	
Construct	X	X	X			X	X
Generate	X		X			X	X
Operate/Perform							X
Choose (attitude)	X			X			X

Figure 1.5: Formats of Criteria-Based Test Items (from Dick and Carey, 1990)

to the knowledge and/or skills the learner can exhibit at some interval of time after instruction or training is completed.

<u>1.5.3 Control groups.</u> The method of using a control group can be used to determine the amount of learning from an instructional system. According to Goldstein (1993), the use of control procedures makes it possible to "specify whether the changes in the experimental group were due to instructional treatment or to other factors, like the passage of time, maturation factors, or events in the outside world." Typically, using a control condition means comparing a group of subjects who receive instruction to a group who do not. However, the term "control condition" has a slightly different meaning in the context of this study. The control condition in this research was the first instructional

treatment, in which subjects were given a printed form of the material to be learned. It is referred to as a control condition because it is a form of instruction that is already widely used, one with which college students are very familiar, and because the two multimedia instructional treatments were being measured against it.

1.5.4 Validity. When designing an experiment to evaluate the effectiveness of an instructional system, four factors exist that can become significant sources of error (Goldstein, 1993). They are (1) statistical conclusion validity, (2) internal validity, (3) external validity, and (4) construct validity. Goldstein (1993) stressed that, of these four, internal and external threats to validity are the most critical. These threats to validity were described in detail by Cook and Campbell (1978) and by Goldstein (1993).

The issue of internal validity refers to whether the treatment itself is responsible for any learning that occurs, or whether there were threats to internal validity that may have affected the results. Specific threats to internal validity that are relevant to this study (adapted from Cook and Campbell, 1978) are outlined below:

History refers to events other than the learning treatment that could occur between learning measurements that could contribute to the results.

Maturation refers to any physical or psychological events that normally occur over the passage of time, such as fatigue or waning interest, that could contribute to the results.

Differential selection of participants refers to situations in which volunteer subjects are used in one instructional condition and randomly selected subjects are used in another. In these cases experimental biases can occur.

Interactions can occur, in which some of the preceding factors, such as maturation and selection, can interact to create an internal threat to validity.

The issue of external validity refers to the generalizability of the results of the evaluation study to other groups of learners (Goldstein, 1993). Goldstein further stressed that a study can only be externally valid if it is first determined to be internally valid, because results must first be generalizable to the original group of subjects before they can be generalizable to other groups. Thus, the threats to external validity can be described as those factors that may limit such generalizations (Goldstein, 1993). Specific threats to external validity that are relevant to this study (adapted from Cook and Campbell, 1978) are outlined below:

Interaction of selection and experimental treatment denotes a case in which there are special characteristics of the group being used for evaluation, such as all being selected from a particular division of a company, that could make the results obtained about that group less generalizable to another group or groups.

Interaction of experimental arrangement denotes a case in which subjects exhibit altered behavior because they realize they are in an experiment. This could cause results to be less generalizable to learners who would not be taught in an experimental setting.

1.6 Summary

1.6.1 Summation of reviewed knowledge and research. The purpose of this research was to compare two computer-based interactive multimedia instructional systems with a more traditional, printed version of the same instruction. It was anticipated that this would reveal significant differences in the degree of learning that occurred among subjects depending on which instructional treatment each was given. The preceding review of research literature as it relates to this study can be summarized as follows:

1) The degree or amount of learning is what was measured. Human learning is a function of human memory, which is comprised of two parts: working (or short-term memory) and long-term memory. It has been determined that there are optimum ways to present memory with stimuli (display modality) to maximize the efficiency and effectiveness of encoding and retrieval in working memory.

2) It is important to be aware of factors that affect the retrieval of information in working memory. These include time of exposure to stimuli, attention demands on the learner, and the amount of information being presented.

3) The subject material was common to all three training treatments, and consisted of selected aspects of performing a work measurement technique known as Time Study Analysis. This selected material can be classified one of two ways: (1) material that requires learners to remember and state or write specific facts (verbal information skills), and (2) material that requires learners to use knowledge and skills to manipulate symbolic information and solve problems (intellectual skills).

4) Since three instructional treatments were compared, their design and development were treated appropriately, using a systematic approach to training systems design. The foundation for this approach begins with the development of behavioral objectives, which specify the information or skill to be learned, the conditions of learning and performance, and the acceptable performance criteria.

5) Once the behavioral objectives have been established, development of the instructional system can be undertaken. To ensure that an instructional system will result in learning the following factors must be considered and dealt with appropriately: learner motivation, selection of appropriate media for the subject material, and proper incorporation of pre-instructional activities.

6) Two of the three instructional systems used as training treatments were presented in a computer-based multimedia format. Design and development of these systems required the examination of many parameters and the elimination of many obstacles. Research on the use of these systems for instruction suggests two things: (1) that the use of engaging media technology can aid in instruction and user satisfaction, and (2) that using these media to create simulated learner experiences and activities can also aid in instruction.

7) Instructional simulations called business games have been developed to teach management and interpersonal skills. These simulations use the physical fidelity of a mock company setting to provide the psychological fidelity needed to reproduce the necessary behavioral processes. Since the material taught (Time Study Analysis) is ultimately an investigative procedure used in industrial settings, this kind of simulation can provide a rough guide for developing an interactive multimedia system that creates a parallel learning environment. Recall that much of

the literature reviewed stressed that authentic learner experiences, which can be easily and accurately simulated by IM systems, can be an extremely valuable instructional tool; this kind of tool is not easily available to instructors when computer-based multimedia is not at their disposal.

8) Each training treatment must be evaluated so that its effectiveness can be compared with the effectiveness of the other treatments. A true experimental design (as opposed to a pre-experimental or quasi-experimental design) must be used to control for an assortment of threats to the validity of the experimental results.

1.6.2 Experimental objectives. Each training treatment was developed using the same set of behavioral objectives. Also, subject learning was measured using the same post-test for all three treatment conditions. The three treatments used for this study can be described as follows: Treatment 1 was a multi-page text document with accompanying pictures and diagrams. Treatment 2 was a computer-based, interactive multimedia system that incorporated color graphics, animations, digital video, and digital audio to present the instructional material. Treatment 3 was a computer-based multimedia system that used the attributes of modern multimedia to simulate a series of learner experiences and activities during a typical day on the job in a manufacturing corporation. The differences between the three treatments, obviously, were confined mostly to the media formats and contexts within which the instructional material was presented.

Since the method of measuring subject learning consisted of a single post-test, it is important to acknowledge that the type of learning being measured is "original learning." Original learning is that which has taken place immediately after instruction. Other categories of learning, such as retention and transfer, were not examined in this research.

There were three basic objectives of this study. First, the effectiveness of computer-based multimedia for instruction was tested. Second, a possible interaction between the method of instruction subjects received and their degree of learning of intellectual skills versus verbal information skills was examined. Third, the relative effectiveness of each multimedia instructional system was explored. These objectives are summarized by formal statements of hypotheses. They are given below.

H_1: Subjects who are given either multimedia treatment condition will exhibit a greater degree of original learning of both verbal information skills and intellectual skills than subjects who are given the control condition.

H_2: Subjects who are given either multimedia treatment condition will exhibit a greater predicted increase in degree of original learning of intellectual skills versus the corresponding increase in learning of verbal information skills.

H_3: Subjects who learn using the multimedia simulation system, which teaches the prescribed content through a series of simulated activities and experiences, will exhibit a greater degree of original learning of both verbal information skills and intellectual skills than subjects who are presented the standard form of multimedia instruction.

2. EXPERIMENTAL METHOD

2.1 Overview

As previously explained, this study compared two computer-based methods of instruction with a textual method (control condition). As indicated by the experimental hypotheses, the variable measured was the degree of original learning (for both verbal information and intellectual skills) among subjects for each instructional treatment. The following sections describe the content and organization of instructional material, the nature of each instructional treatment condition, the specific experimental design used, and the methods of measuring and comparing subject performance for each treatment condition.

2.2 Instructional Content and Organization

The instructional content consisted of selected material related to the work measurement technique Time Study Analysis. In general, time study analysis is a method of establishing a time standard, usually for some industrial task or operation. The content of instruction for this research, although it was not comprehensive, included information about the reasons a time study is performed, the meaning of the results of a time study, required pre-data collection activities, and data collection and analysis procedures. Once the instructional treatment condition had been administered, subjects completed a post-test to measure their degree of original learning of the prescribed content.

The instructional content was common to all treatment conditions. A specific list of behavioral objectives was compiled to serve as a guide for the structure and organization of the material within each treatment condition. These behavioral objectives are separated into groups for those pertaining to verbal information skills and intellectual skills. They are outlined below. Note that these objectives do not conform completely to the rules of developing behavioral objectives because they do not specify acceptable levels of learner performance. However, the purpose of this study is not only to simply determine whether a particular method of instruction is effective, but also which of the instructional methods is *more* effective than the others. Thus, specific performance criteria are unnecessary.

Behavioral Objectives (verbal information skills)

1. Define on a written test a "time standard."
2. Identify on a written test two reasons that knowing times for the individual components of a job or task is useful to a company.

3. Identify on a written test the four basic items of equipment necessary to perform a time study.
4. Identify on a written test the essential quality to look for when selecting an operator to observe for a time study.
5. On a written test, when presented a blank Form 7 data sheet, identify the following sections: cells for listing job elements, cells for recording elapsed times, and cells for recording net element times.
6. Identify on a written test the six basic steps involved in collecting the actual time data.
7. Identify on a written test the four basic steps in calculating the time standard from the time data.

Behavioral Objectives (intellectual skills)

8. On a written test, when presented a sample set of time data (on a Form 7), calculate the individual element times and record them in the appropriate cells.
9. On a written test, when presented a sample set of time data (on a Form 7) and the corresponding individual element times, identify any outliers among the individual element times.
10. On a written test, when presented a set of individual element times adjusted for outliers, calculate the average element time for each individual element of the operation.
11. On a written test, when presented a set of averaged individual element times adjusted for outliers, calculate the time standard.

2.3 Treatment Conditions

Since this experiment examined the relative effectiveness of three instructional methods, several variables had to be controlled in order to draw meaningful conclusions from the data. Appendix A contains the complete textual instruction used as the control condition for the study. Appendices B and C contain descriptions and layouts of the two multimedia treatment conditions. Note that their content and wording mirror that of the control condition as closely as possible. By eliminating differences in the content between treatment conditions, there is a greater chance of showing that the method of instruction is the factor affecting subjects' original learning. Each of the three instructional treatment conditions contained essentially the same content, but there were important differences in the method of delivery between the control condition and the two multimedia treatment conditions. Since both multimedia conditions appeared and functioned similarly, the *exact* differences between each must be specified in detail (see Appendices B and C for complete descriptions).

One hypothesis of this study stated that the third treatment condition (multimedia simulation) would result in greater original learning of verbal information skills and intellectual skills than either of the other two instructional conditions. This might seem obvious when comparing the third condition to the control condition (text), but not so obvious when comparing the third condition to the other multimedia condition (standard multimedia). The two multimedia conditions were nearly identical in many ways: they shared the same basic interface layout and functions, they contained the same instructional content, and they both made use of the same media format for information presentation (i.e., if audio was used to present certain kinds of information in one multimedia condition, then it was also used to present that information in the other multimedia condition).

These close parallels between the two multimedia instructional conditions served to emphasize and isolate the differences between them. Essentially the differences between the two conditions were confined to the manner in which the learners and the multimedia systems interacted with each other. Recall that Heller (1990) proposed two basic approaches to IM system design: knowledge presentation and knowledge construction. She described knowledge presentation systems as ones that make little attempt to actually teach users, and often rely heavily on their visual and auditory effects to present information. Conversely, knowledge construction systems have highly organized and structured information, and often incorporate interactive "experiences" to teach users. The first multimedia approach (second treatment condition) used in this study cannot accurately be described as a knowledge presentation system since its information was highly organized and structured, and since its purpose was clearly to *instruct*, not just to *present.* However, it did rely heavily on its use of multiple media formats to teach users. Also, its content, although well-organized and structured, was not presented within any underlying context; it was simply presented. This lack of underlying context for the presentation of the instructional material was the critical difference between the first and second multimedia instructional treatments.

As mentioned earlier, the second approach to multimedia instructional system design (third treatment condition), was based on a knowledge construction approach, which allows learners to "construct" knowledge in a personalized manner through simulated activities and experiences. A contextualized computer environment (CCE) is one that utilizes pictures, sound, animation, and motion video to illustrate key ideas or even stories that will actively engage the learner. According to Heller (1990), a CCE lends itself well to the knowledge construction approach. The third instructional treatment in this study represented a true contextualized computer environment, since it presented the same organized, structured material, but within the underlying context of a simulated manufacturing setting. It engaged learners in a variety of activities such as interacting with co-workers, moving through different areas of the plant, and observing workers as they performed some basic manufacturing operations.

Since the nature of each computer-based multimedia treatment condition was somewhat dissimilar to the control condition and to each other, there was the distinct possibility that experimental results could be affected by another factor: if a treatment was poorly designed then it might very well have proven to be an ineffective instructional system. This could lead to the erroneous conclusion that its *method of delivery* was inferior when just the opposite might have been true. To control for this possibility, both multimedia treatment conditions were developed according to the recommendations contained within the review of the literature. Specifically, the following literature was consulted in the design of each condition: the model developed by Reiser and Gagné (1983) for selecting media for instruction, the findings of Wickens (1992) concerning working memory code and display modality, the suggestions and recommendations of numerous authors concerning screen layout, the use of text, color, graphics, audio, video, and the implementation and use of "browsers," the suggestions and recommendations of numerous authors concerning the distinct similarities and differences between knowledge presentation and knowledge construction forms of multimedia instruction, the suggestions and recommendations of numerous authors concerning the effectiveness of instructional simulations, and finally the development of The Looking Glass, Inc. instructional simulation by McCall and Lombardo (1982).

2.4 The Post-test

The degree of original learning among subjects was measured using a post-instructional test (Appendix D). This type of test is only capable of measuring original learning (as opposed to transfer or retention) since it is administered immediately after the instructional treatment. The test for this experiment was divided into two sections: section

1 tested subjects' verbal information skills and section 2 tested subjects' intellectual and problem-solving skills. The behavioral objectives outlined in section 2.2 were used to compose each test question.

The verbal information section of the test was written using a multiple-choice format in order to facilitate grading and to eliminate subjective bias by the grader (the response was either correct or incorrect). Each question provided five response choices. Each incorrect choice was carefully written to seem plausible, and in no case was there more than one choice that could be considered correct. Based on the content of the instruction, each incorrect response was clearly and indisputably flawed.

The intellectual skills section of the test was written using a problem-solving format. Subjects were asked to perform calculations based on their knowledge of procedures and rules governing the analysis of time data. In grading this section of the test, the correct numerical answer was not the sole criterion for a correct response; subjects were required to show their work. Grading for each problem-solving question was standardized to minimize any subjective bias, but the grading scheme for this section was not determined until experimental pre-testing was completed. Section 2.7 (Preliminary Testing) contains the complete standardized grading scheme for the problem-solving section of the post-test. When this portion of the test was administered, subjects were provided with a calculator and tables to use in applying the Dixon test for adjusting time data sets. They were also provided with additional, unnecessary tables and figures.

The post-test items were carefully sequenced. In many cases questions were worded in such a way that they revealed the answer to one or more previous questions. Therefore, subjects were not allowed to return to a previous question to change a response once that question had been answered. This somewhat unusual procedure was thoroughly explained to each subject prior to administration of the post-test.

2.5 Subjects

The subjects used for this experiment were 30 college students enrolled in any of Virginia Tech's engineering programs other than Industrial and Systems Engineering (ISE). ISE students were only considered for participation if they had not previously taken, or were not then taking the ISE Work Measurement and Methods course (time study analysis is among the topics presented in this class). Ten subjects were randomly assigned to each treatment condition. Subjects were paid $5.00 per hour for their participation.

A major concern in the design and evaluation of any instructional program is the inherent individual differences among persons undergoing the instruction. These differences include prior knowledge of subject material, previous experience with similar environments or systems, learning styles, and overall aptitudes as they relate to the nature of the subject material. These individual differences, coupled with a relatively small sample size (as in the case of this study), can make it difficult to show any significant effects between instructional treatments. To reduce the possibility of this outcome, subjects were screened to ensure similarities in knowledge and skills, and to ensure no previous knowledge or experience with time study analysis or computer-based multimedia training programs. Engineering students were selected as subjects in an attempt to achieve the goal of a common base of knowledge and skills (related to mathematics and engineering) among subjects. A short questionnaire (Appendix E) was used during selection of subjects to ensure that none had had any extensive exposure to computer-based multimedia training programs or any exposure at all to the principles and procedures of time study analysis.

2.6 Experimental Design

The experimental design used was a two-factor, mixed factors design. The between-subjects variable (three levels) was Method of Instruction (control, standard multimedia, and multimedia simulation). The within subjects-variable (two levels) was Domain of Learning (verbal information skills and intellectual skills). This was a control group design, which normally implies that one set of subjects would receive no instructional treatment at all. In this case, however, the relative effectiveness of each treatment was being measured and compared, so the control group received a traditional form of instruction (textual) instead of no instruction at all.

2.7 Experimental Procedures

2.7.1 Assignment of subjects to groups. Subjects participated in the study in sequential order, meaning the first subject to participate was called "subject 1" and the last to participate was called "subject 30." Figure 2.1 shows a table that designates the group to which each successive subject was assigned. This table was constructed using a random number generator, generating random numbers between 0 and 1.0. Each of the three instructional conditions corresponded to a block of numbers representing one-third of this range of values (0 - 0.33 corresponded to the Control Condition, 0.34 - 0.67 corresponded to treatment 2, and 0.68 - 1.0 corresponded to treatment 3). Beginning with subject 1, a random number was generated that fell within the first range of values. Thus, subject 1 was assigned to receive the control condition. Each successive subject was assigned a treatment condition in this manner. Figure 2.1 represents the experimental design with subjects assigned to treatment conditions.

	Instructional Treatment		
Domain of Learning	Control	Simple Multimedia	Multimedia Simulation
Verbal Information	s1 s13 s6 s16 s8 s20 s9 s24 s12 s25	s2 s21 s5 s27 s7 s28 s14 s29 s17 s30	s3 s18 s4 s19 s10 s22 s11 s23 s15 s26
Intellectual Skills	s1 s13 s6 s16 s8 s20 s9 s24 s12 s25	s2 s21 s5 s27 s7 s28 s14 s29 s17 s30	s3 s18 s4 s19 s10 s22 s11 s23 s15 s26

Figure 2.1: Experimental design with subject assignments

In an effort to control all independent variables unrelated to the differences inherent among the three instructional treatments, each subject's exposure to the instructional content, regardless of treatment condition, was governed by certain constraints. In accordance with the recommendations of Dick and Carey (1990) and Gagné (1993), all subjects, before receiving any instruction, were given a brief overview of the instructional content and were informed that they must not neglect any portion(s) of the instructional content. Furthermore, subjects were told that they would be tested at the end of the session, and that they should use the instructional system to "study" for that test. In addition, subjects were given a maximum time limit to complete both their review of the instructional content and their completion of the post-instructional test. As with the post-test grading schemes, these time limits were not established until preliminary testing was completed. Section 2.8 (Preliminary Testing) outlines these time constraints.

2.7.2 Data collection room. All subjects were given training treatments in a common room. This room contained two tables, one whose surface was bare and one which supported the multimedia delivery system. Control group subjects reviewed the control condition while seated at the bare table, while subjects who used either of the multimedia treatment conditions were seated in front of the multimedia delivery system. All subjects used the bare table to complete the post-test.

2.7.3 Multimedia delivery system. Instructional material for both of the two multimedia treatment conditions was presented using a Macintosh Quadra 840 A/V for multimedia delivery. This computer was equipped with 32 megabytes of Random Access Memory (RAM) which was sufficient for either multimedia program, and was also capable of 32-bit display mode (16.7 million colors). Both treatment conditions were presented using a standard 13-inch (640 x 480 pixels) monitor. Interaction with either of the two multimedia systems was accomplished by using a mouse; a keyboard was also present (though it was disabled) to give the machine a standard desktop computer appearance.

2.7.4 Experimental Protocol. Upon arriving at the Human-Computer Interaction Laboratory, each subject was asked to read a set of instructions (Appendix F) and complete an informed consent form (Appendix G). Once informed consent had been obtained the experimenter reviewed the purposes and procedures of the study and answered subjects' questions.

Once each subject and the experimenter had completed these preliminary procedures, subjects were presented with the assigned instructional treatment. If one of the multimedia treatment conditions was to be presented, the experimenter first explained that subjects were encouraged to ask for assistance if they encountered difficulty in using the multimedia system. However, subjects were also told that they would not be provided with any assistance regarding the instructional content. The experimenter remained present in the room during testing to monitor each subject (in case problems arose with multimedia system function or navigation) and to administer the post-test. Once the post-test was completed subjects were paid and thanked for their time.

2.8 Preliminary Testing

Preliminary data collection was performed using four subjects. The results of this preliminary data collection revealed several problems that had to be addressed before actual data collection could be undertaken. Specifically, subjects were scoring too well on the post-test regardless of which instructional treatment condition they were given. Also, subjects were completing their study of the instructional material (regardless of treatment condition) very early, usually within 30 minutes. Thus, the following changes were made.

2.8.1 Changes in Experimental Procedure. The time on training task for all three instructional conditions was reduced from 90 minutes to 30 minutes. The time for post-test completion was also reduced, from 60 minutes to 30 minutes.

2.8.2 Changes in Experimental Post-test. The verbal information portion of the test, which was formerly comprised solely of multiple-choice questions, was modified so that five of the nine questions were presented in a short-answer format. Subjects reported they were often able to determine the correct response on multiple-choice questions by reviewing and eliminating the incorrect choices. Thus, that portion of the test became an exercise in recognition, not recall, for those subjects. The four remaining questions, which preliminary data showed to be more challenging, were kept in their original multiple-choice format.

The intellectual skills portion of the test was also modified to make it more difficult. For the second question in that portion of the test subjects were given a set of time data and asked to adjust it for any outliers. Upon initial inspection there appeared to be two outliers. However, if the calculations were performed properly, it became clear that there were no outliers and the data set did not need to be adjusted at all.

Despite these changes, the items in the modified experimental post-test were still consistent with the original behavioral objectives outlined in section 2.2 (Instructional Content and Organization).

2.8.3 Changes in Post-test Grading. After changes were made to the post-test, the verbal portion contained nine questions; five short-answer and four multiple-choice. The short-answer questions were each worth 12 points each, and were scored using a five-step scale. Specifically, each response was awarded 0, 3, 6, 9, or 12 points depending on its "degree of correctness." Established guidelines for "degree of correctness" for these five questions are provided in Appendix E. A similar scheme was used to grade the intellectual skills portion of the test. However, this portion only contained four questions, so each was worth 25 points and each was graded using a six-step scale. A response was awarded 0, 5, 10, 15, 20, or 25 points depending on its "degree of correctness" (see Appendix E).

3. EXPERIMENTAL RESULTS

3.1 Overview

Preliminary testing was performed and data were collected to identify (and subsequently correct) any flaws or problems with the presentation or format of the instructional treatment conditions, the design of the post-test, or other data collection procedures. With the collection process revised and refined, data for the actual experiment was then collected. The data were organized and tabulated, and statistical analyses were performed to determine what results might be represented by the data.

3.2 Post-test Scores

Once each subject had completed the experiment, his or her experimental post-test was graded and the results were tabulated. Table 3.1 shows the complete set of post-test scores (with each corresponding treatment condition) arranged based on order of subject participation. This table represents the data as it was collected chronologically.

Table 3.1: Post-test Scores Based on Subject Order

Subject	1	2	3	4	5	6	7	8	9	10
Treatment Condition	1	2	3	3	2	1	2	1	1	3
Verbal Test Score	84	94	57	84	84	84	77	90	74	90
Intellectual Test Score	65	90	85	100	100	90	40	100	50	85

Subject	11	12	13	14	15	16	17	18	19	20
Treatment Condition	3	1	1	2	3	1	2	3	3	1
Verbal Test Score	82	69	78	87	94	59	85	69	97	59
Intellectual Test Score	25	25	75	100	100	65	80	75	25	75

Subject	21	22	23	24	25	26	27	28	29	30
Treatment Condition	2	3	3	1	1	3	2	2	2	2
Verbal Test Score	78	65	78	82	69	97	77	59	90	94
Intellectual Test Score	80	80	85	25	35	90	80	100	100	85

key: 1 Control Condition
2 Standard Multimedia
3 Multimedia Simulation

Table 3.2 shows the means and standard deviations for test scores for each subject group for the verbal information and intellectual skills portions separately, and for the combined scores for each group. This table also represents the complete set of post-test scores as a matrix of instructional treatment condition with domain of learning.

Table 3.2: Means and Standard Deviations for Post-test Scores

	Instructional Treatment		
Domain of Learning	Control	Simple Multimedia	Multimedia Simulation
Verbal Information	84 78 77 59 74 59 90 82 69 69	94 78 84 77 90 59 87 90 85 94	57 69 84 97 91 65 82 78 94 97
	Mean: **74.1** Std. Dev.: **10.2**	Mean: **83.8** Std. Dev.: **10.5**	Mean: **81.4** Std. Dev.: **14.0**
Intellectual Skills	65 75 40 65 50 75 85 25 25 35	90 80 90 80 100 100 100 100 80 85	85 75 100 25 85 80 25 85 100 90
	Mean: **54.0** Std. Dev.: **22.0**	Mean: **90.5** Std. Dev.: **8.96**	Mean: **75.0** Std. Dev.: **27.5**

3.3 Data Analysis

The data were analyzed using a three-by-two, mixed factors Analysis of Variance (ANOVA). The first factor, Method of Instruction, was a between-subjects variable with three levels (control, standard multimedia, and multimedia simulation). The second factor, Domain of Learning, was a within-subjects variable with two levels (verbal information and intellectual skills). The ANOVA was performed using an alpha level of 0.05. Table 3.3 summarizes the statistical results of the ANOVA. The table categorizes effects into between and within-subjects variables. The asterisk accompanying the F value for the main effect of Instructional Method indicates that this factor showed (statistically) a significant effect on subjects' original learning. The absence of asterisks with the effects of Domain of Learning and of the interaction of Instructional Method with Domain of Learning indicates that these did not show (statistically) a significant effect on subjects' original learning.

Table 3.3: ANOVA Summary Table

Source	df	SS	MS	F
Instructional Method (M)	2	5426.2	2713.1	**9.80***
Subjects/M	27	7473.7	276.8	
Domain of Learning (D)	1	653.5	653.5	**2.12**
D x M	2	1795.9	897.9	**3.00**
D x S/M	27	8099.7	299.9	
Totals	59	23448.9		

The ANOVA shows that the interaction between Instructional Method and Domain of Learning was not significant. The analysis does show that Instructional Method had a significant effect on subjects' original learning, but it does not show which levels of this factor were significantly better (or worse) than which other levels. To determine the locus (or loci) of this main effect, a Newman-Keuls post-hoc test was performed. Table 3.4 summarizes the results of the Newman-Keuls test.

Table 3.4: Newman-Keuls Test for Unplanned Comparisons

Increasing Order

Treatments	**Control**	**Simulation**	**Standard**		
Means	**64.05**	**78.20**	**87.15**	r	CD_{N-K}
1	--	14.15	**23.10***	3	18.46
2		--	8.95	2	15.26

As before, an asterisk denotes significance, but in this case the asterisk indicates a significant difference in the effect of one level as compared to the other. The Newman-Keuls test shows only that treatment 2 (standard multimedia) resulted in significantly better original learning than the control condition. Although there are differences in mean scores in comparisons of treatment 3 (multimedia simulation) with the control condition and of treatment 2 (standard multimedia) with treatment 3 (multimedia simulation), these differences are not statistically significant.

4. DISCUSSION

4.1 Overview

This research was intended, in part, to show experimentally that computer-based multimedia systems can be far more effective as instructional devices than more traditional, text-based devices (such as textbooks). For this study numerous articles and studies were reviewed which cautioned that there are many ways to design and develop multimedia systems, some better than others. Some articles specifically suggested that using multimedia technology to simulate activities and experiences for the learner can further enhance a system's instructional effectiveness. Thus, this research was extended also tested the effectiveness of this type of multimedia instructional program.

There is a simple rationale behind the choices for each of the instructional treatment conditions. If analysis of the experimental data revealed that the multimedia systems were more effective than the control condition, then hopefully it can be concluded with some certainty that computer-based multimedia instruction is generally superior to text-based instruction. Furthermore, if the multimedia simulation system was found to be highly effective, then hopefully something has been learned about how to design and develop these superior multimedia instructional systems to take full advantage of their awesome capabilities.

4.2 Efficacy of Multimedia Instruction

Perhaps the single most important outcome of this research is the effectiveness of the standard multimedia system over the control condition. This confirms that computer-based multimedia systems *can* be excellent instructional devices. However, it would not be entirely correct to make the broad conclusion from the data analyses that multimedia is better than text alone, since one of the multimedia systems was shown to be significantly better but the other was not. Nevertheless, the results of the analyses are very informative. What the results really show is that multimedia systems can be more effective, but only when they are properly designed and developed for the given subject material and learner audiences.

4.3 Comparison of Multimedia Conditions

The experimental results show that only the standard multimedia system was significantly more effective than the control condition. The following sections attempt to provide explanations for the success of the standard multimedia system and the lack of success of the multimedia simulation system.

4.3.1 Effectiveness of Standard Multimedia System. It is not surprising that the standard multimedia system resulted in superior subject performance. Learning involves processing, storing, and retrieving information in human memory, and the characteristics of the computer-based multimedia environment are clearly better suited for this process. There are several reasons the standard multimedia system proved to be such an effective instructional device. First, the system was designed to present information in optimum display modalities simultaneously by using digital video, audio, animations, and other visual aids (a complete description of the standard multimedia system is contained is Appendix B). When explaining specific actions the learner must take the program uses video (with audio) to show appropriate examples. When describing the assembly of a faucet the program uses simple animations to show how the pieces fit together. When explaining the calculations involved in data analysis the program shows numbers filling into appropriate cells and computations performing themselves. It is likely that this resulted in better encoding and processing of information and increased the ease and depth of information retrieval among learners. Also, providing clear, concise text messages with the other visual and auditory information likely reinforced the material being presented to the learner. It is also likely that the engaging visual and auditory effects greatly enhanced learner motivation, another key to effective instruction.

Another positive attribute of the standard multimedia system was the level of interactivity afforded the learner. Subject material was neatly divided into four topic areas that the user could select at any time. In addition, users were given a set of buttons that provided control over the pace with which instructional material was presented to them (see Appendix B). Always the learner had the ability to repeat messages or visual aids to reinforce the instructional material.

4.3.2 Inferior Performance of Multimedia Simulation. The multimedia simulation condition presented the prescribed instructional content by embedding it within a set of fictitious "events." These events were intended to provide the "activities and experiences" that Heller (1990) and others proposed would enhance the learning experience. Judging from the results of the data analyses, however, this approach apparently hampered learning instead of improving it. There are several possible reasons for this finding. One possibility is that the events and activities created to enhance learning somehow diverted subjects' attention from the actual instructional content. Indeed, some subjects (in discussions with the experimenter after testing was completed) observed that they felt compelled to pay close attention to the "storyline" that the program was presenting and devoted less mental effort to actually learning about time study analysis.

Another possible reason for the performance of the multimedia simulation is individual differences among subjects. The process of learning is completely unique to every individual. These differences present a certain level of variability that can be controlled for with large sample sizes and careful subject selection, but they can never be completely eliminated. These differences include prior knowledge of subject material, previous experience with similar environments or systems, learning styles, and overall aptitudes as they relate to the nature of the subject material. Subjects for this study were carefully selected to ensure a similar base of prior knowledge and skills and no experience with similar environments or systems. But learning styles and overall aptitudes are traits unique to every individual and cannot be predicted or controlled.

Another possible reason for the performance of the multimedia simulation is subjects' navigation through the program. During data collection, subjects were allowed 30 minutes to review the instructional material. Preliminary testing had revealed that subjects generally needed about 20 minutes to review the content once, leaving the remaining ten minutes for them to review any areas of the material they had originally found difficult or confusing. For subjects who used the Control Condition, this backtracking was accomplished by simply flipping back through the pages until the desired segment of material was found. For subjects who used the Standard Multimedia program, this was accomplished by simply clicking on any of the global buttons on the screen. These buttons were clearly labeled (accompanied by icons) with the names of each distinct topic area. For subjects who used the multimedia simulation program, however, this task was slightly more difficult. As with the Standard Multimedia program, global buttons with labels were always available, but the labels did not reflect topic areas; instead they represented different centers of activity (such as "Stockroom") within the ACME Faucet Corporation (the fictitious company that subjects "worked for"). Thus, it was not intuitively obvious to subjects which button to select to review a specific topic area, possibly creating additional confusion and uncertainty and using extra time.

Another possible reason for the performance of the multimedia simulation is fidelity of simulation. The objective of an instructional simulation is to create psychological fidelity through physical fidelity (Goldstein, 1993). This means that the behavioral processes needed to learn the task are recreated in the training tasks. In the case of the multimedia simulation treatment condition, the tasks created were intended to provide physical fidelity by establishing and maintaining the atmosphere of an industrial setting. Some simulations, such as flight simulators, are able to produce an extremely high degree of physical fidelity by providing representative stimuli to all the body's senses. This is often very effective because it genuinely gives learners the feeling that they are participating in actual events, not just a simulation. Unfortunately, at this point in time there is a very low ceiling on the amount of physical fidelity that can be created by a images and sounds on a 13-inch computer screen. It is entirely possible that the multimedia simulation program simply lacked the physical fidelity required to create the psychological fidelity within the minds of learners. Thus, this treatment condition fell short of its lofty expectations.

4.4 Future Research Possibilities

Essentially, two of the three hypotheses were shown to be generally true. Both multimedia systems clearly outperformed the text-based Control Condition, strengthening the validity of the assertion that multimedia is generally a more effective instructional medium than text for verbal information and intellectual skills. As stated earlier, it would probably be premature to conclude (from the data) that a multimedia simulation is less effective than a more Standard Multimedia system. Thus, the question remains: what is the best way (and within what context) to design and produce a multimedia instructional system that will result in optimal learning? After all, designers and developers have a number of options when undertaking the task of creating a multimedia instructional system. These must be further examined and researched so that designers/developers will have a sound understanding of how to approach, design, and implement their systems.

The concept of simulation of events and activities in a multimedia environment should not be discarded based solely on the results of this research. The key to an effective simulation is the psychological fidelity in the mind of the learner that results from the physical fidelity provided by the simulator. The simulation treatment condition used in this research probably did not provide an adequate degree of physical fidelity. If it is indeed true that more physical fidelity is required to produce an effective multimedia instructional simulation, then techniques must be developed to ensure that this fidelity is provided by the system. The elements of the simulation must be convincing enough to create the important psychological fidelity needed to result in learning.

In the case of the simulation developed for this study, the atmosphere of the mock industrial environment needed to be much more thorough, with greater attention to detail.

One way to improve the simulation would be to incorporate many characters into the setting, using digital video to introduce them and to effect their interactions with learners (whereas the simulation used for this study used still pictures with voices). The production of the instructional system would not be unlike the production of a movie; digital video could be the main presentation medium and whole sets could be built and actors and actresses enlisted to play the roles of the characters learners are meant to encounter.

Another way to improve the simulation would be to provide learners with a problem (or perhaps even a mystery) to force them to think and make decisions in order to solve the puzzle. The system could provide a large number of different possible outcomes for each correct or incorrect decision, giving learners the opportunity to experience setbacks or reach erroneous conclusions as they attempt to solve the problem they have been given. In short, present learners with a simulation centered around a problem that is truly challenging.

The lack of success with the simulation condition used in this experiment has emphasized the importance of properly designing a multimedia instructional system to ensure that it will be effective. Undoubtedly, there are other approaches (besides simulation) to creating a multimedia instructional system that remain unexplored. One possible approach is to design a fully functional multimedia program in which learners actually play a game. The use of multimedia could ensure that the game is highly attractive and engaging. Learners could receive rewards for correct actions or responses and penalties for incorrect ones. This approach holds a great deal of potential because it could instill tremendous amounts of motivation among learners. Learners could be motivated to "defeat" the game or to see how far they could go with each new playing session. Learners could also compete against one another, comparing personal-best scores and trying to outperform each other. Future research efforts in this area could open up entirely new and exciting avenues for multimedia instructional system design and development.

Still another instructional method that warrants examination is "discovery learning." In a discovery learning environment, images or icons appear on the screen that, when selected by the learner, present a wealth of information about a particular topic. It is usually not entirely clear to the learner just what information will be presented when an image is selected. Thus, the name "discovery learning" is very appropriate. This kind of environment encourages learners to explore all the information that the program contains and allows learners to create individual associative links of information within their own memories. The problem with this kind of environment, however, is that instructors have little or no control over which information learners will be exposed to, or the sequencing of that information. Nevertheless, this approach to multimedia instructional system design also holds significant potential and must be researched as well.

5. CONCLUSIONS

Multimedia technology today is very powerful and is constantly evolving and improving. Its powerful effects and awesome capabilities make it very attractive to many educators who wish to harness this power to instruct students, but digital video and eye-catching graphics alone do not guarantee an effective instructional device. However, multimedia systems do offer a higher level of interactivity than many other forms of individualized instruction; they can present information in more effective combinations of display "modalities," and can certainly use engaging visual and auditory effects to heighten learner motivation. Unfortunately, meaningful research concerning the proper methods of designing and developing multimedia instructional systems (not to mention testing their effectiveness) has barely begun.

This research was undertaken to strengthen and solidify the limited amount of knowledge in this area. The reviewed body of literature concerning both multimedia systems and instructional systems leads to the logical assumptions that multimedia instruction is more effective than traditional text-based instruction, and that a multimedia instructional system that provides simulated experiences and activities can be even more effective. Hypotheses were formulated and an experiment was conducted to examine the validity of these theories.

The most important conclusion to be drawn from this research is that instruction in a computer-based multimedia environment shows enormous potential for resulting in greater learning (at least original learning) than instruction in a text-based environment. This is the first step in making computer-based multimedia a standard element for all instructional settings. Now what is required is research into the best ways to approach the design of an instructional system that takes full advantage of the potential of the multimedia format.

In comparing the standard multimedia system to the control condition, it can be concluded that a computer-based multimedia program (when properly designed and implemented) is a more effective method of individualized instruction (at least for verbal information skills and intellectual skills) than a text-based device. This is not surprising; a multimedia system can present information in optimum display modalities simultaneously, strengthening and reinforcing the message being presented to the learner. By incorporating engaging visual and auditory effects, a well-designed multimedia system can also greatly enhance learner motivation, another key to effective instruction.

The analyses of the experimental data also showed that the multimedia simulation condition was less effective (for verbal information skills and intellectual skills) than the standard multimedia condition. However, it would be premature to conclude that a multimedia system that simulates learner events and activities is undesirable because other methods of multimedia system design and development may be more effective. In all likelihood, a multimedia simulation program *can* be a highly effective method of instruction, but it is obviously very difficult to create and develop a set of related experiences and activities that will enhance the learning process instead of obstructing it. Thus, it is clear that just providing a multimedia system does not ensure that learning will be maximized. Multimedia systems, particularly those used for instruction, must be very carefully designed to be effective teaching devices.

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APPENDICES

APPENDIX A

Instructional Treatment 1 (Control Condition)

Selected Principles And Procedures Of Time Study Analysis

Introduction to Time Study Analysis

A time study is a work measurement technique used by industrial engineers. It usually requires the engineer (that's you) to observe a worker or workers performing some operation and collect time data. There are two basic reasons that time studies are performed:

1. Performing a time study establishes a time *standard.* A time standard is a formal determination of the amount of time it takes to perform a task or operation *when that job is performed by a normal operator working at a normal pace.* Efficient manufacturing involves many activities, such as production scheduling or cost estimating, for which knowing time standards can be very useful.

2. Performing a time study allows the you to examine the time it takes to complete each element of a task or operation. Most manufacturing tasks or operations require multiple steps, or "elements." If any one element takes much longer to complete than the other elements, then the operation is not being done very efficiently. During a time study you make a record of how long it takes to complete each element of the task so that you can determine if any elements are taking too long. Once the inefficient elements have been discovered, you can make changes to the operation to improve its efficiency.

Time Study Equipment

As mentioned earlier, a time study is a measurement technique that involves observing a worker and recording time data. There are four basic items of equipment that you must have to properly record time data:

1. *A stopwatch.* They are a common, efficient means of timing an event, and they are simple to understand and operate.

2. *A Form 7 record sheet.* The Form 7 is a standard data form that is specifically designed to be used in time studies. It allows you to list all the elements of the operation and record the elapsed time (from the stopwatch) as each element is completed. Once the data collection is finished, you can also record the net time for each element on the Form 7.

3. *A time study Board.* This is really just a fancy version of a clipboard. It is designed to hold the stopwatch and the Form 7 data sheet.

4. *A pencil.* You'll needs something to record the time data with. A pencil should be used in case you make errors and need to erase.

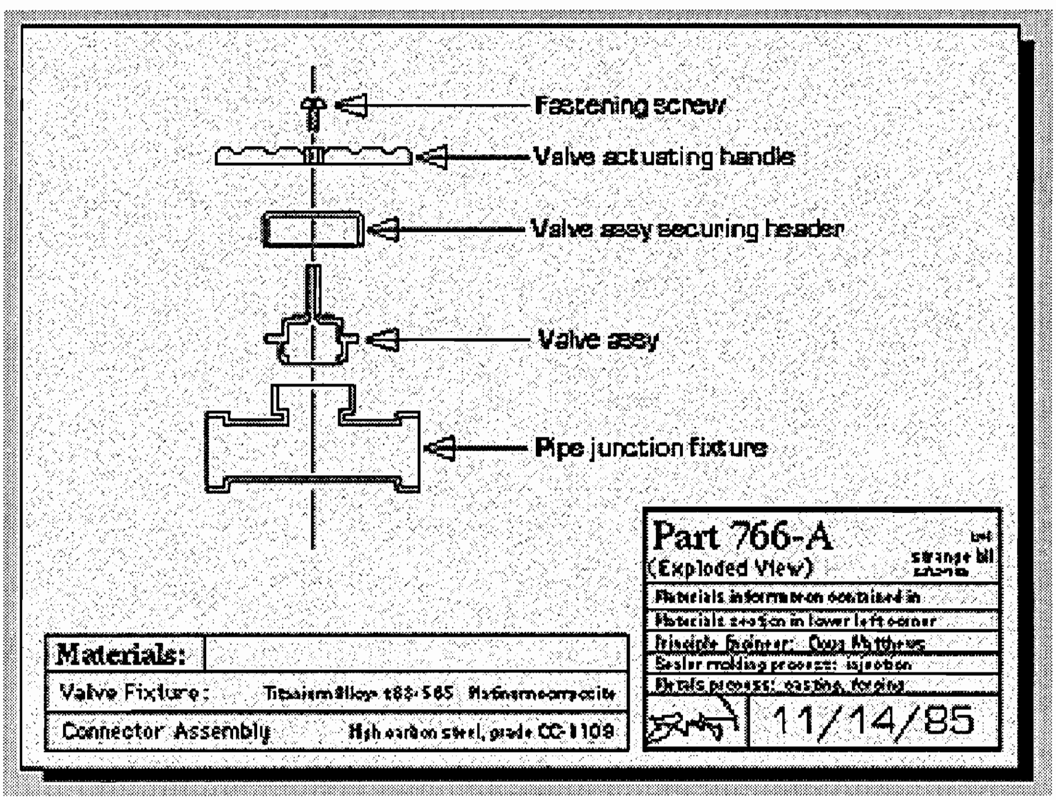
Collecting Time Data

Time studies are performed to establish time standards and to examine specific operational elements. The key to both of these functions is raw time data. To see how to collect time data, let's look at an example. Suppose you wanted to perform a time study of a worker assembling a simple faucet. There are six basic steps involved in collecting time data:

Step 1 *Select an operator to observe.* Usually in a manufacturing setting there are many workers performing the same job concurrently, and you must choose only one for data collection. The operator you choose should work at an average pace, neither too fast or too slow. Recall that one reason for doing a time study is to establish a time standard for an operation, and a time standard is a declaration of how long the operation takes the *average* worker to complete working at a *normal* pace.

Step 2 *Familiarize yourself with the job.* Before you record any time data, it's essential that you watch the worker assemble a few faucets so that you are completely familiar with exactly how he or she does and so that you'll have a rough estimate of the overall cycle time (how long it takes to assemble the faucet from start to finish).

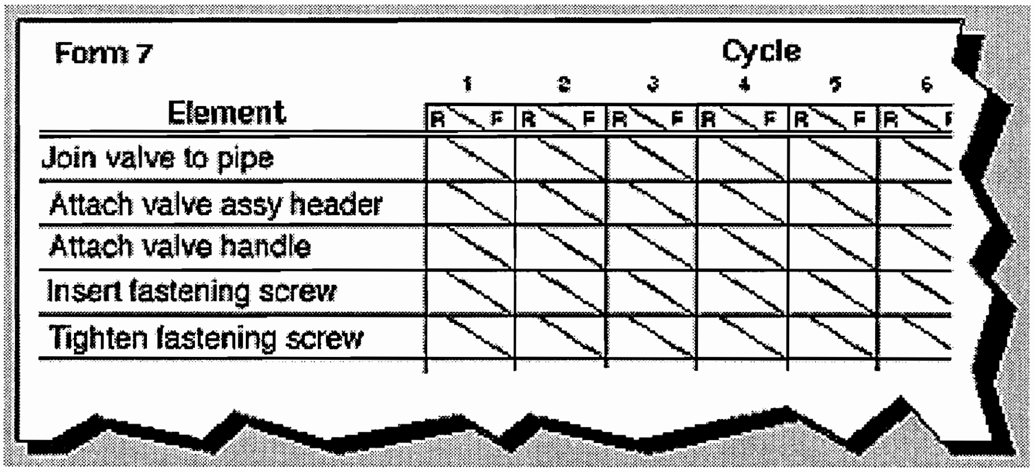
Step 3 *Break down the operation into elements.* Like most operations, the assembly of the faucet requires several different steps. This blueprint of the faucet shows its different pieces and how they go together.



For this example, let's assume you have divided the faucet assembly operation into the following elements:

Element 1: Join valve assembly to pipe junction fixture
Element 2: Attach valve assembly securing header
Element 3: Attach valve actuating handle
Element 4: Insert fastening screw
Element 5: Tighten fastening screw

Step 4 List the elements on the Form 7 for data recording, like this:



Form 7

Element	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
	R \ F	R \ F	R \ F	R \ F	R \ F	R \ F
Join valve to pipe						
Attach valve assy header						
Attach valve handle						
Insert fastening screw						
Tighten fastening screw						

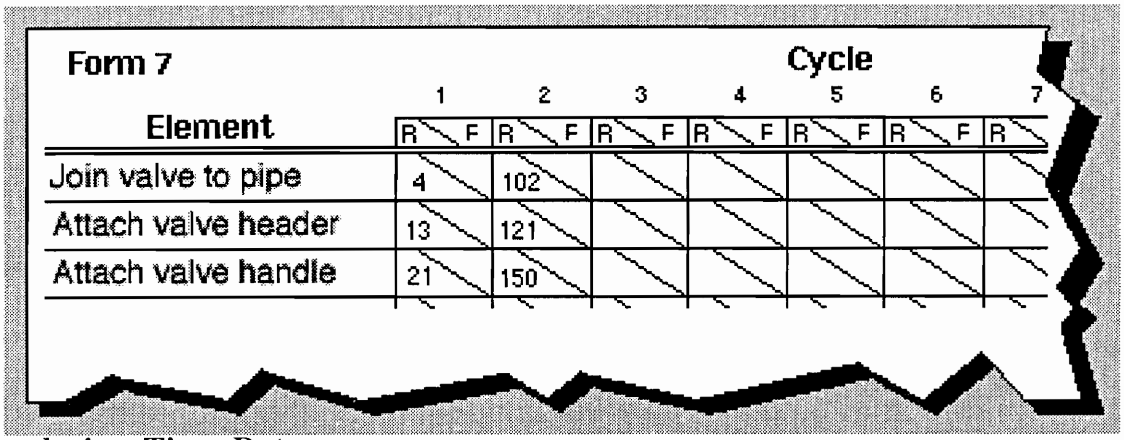
Step 5 *Determine the number of operational cycles to observe.* When the worker completely assembles one faucet, he or she has performed one *cycle* of the operation. To make sure your results are accurate, you must observe and collect time data for a number of cycles. There are set standards for how many cycles should be observed depending on your estimate of the overall cycle time (from Step 2). This table shows exactly how to select the number of cycles to observe based on the overall cycle time estimate. For example, if the faucet assembly operation takes about 30 seconds (or 0.5 minutes) then you should observe and collect time data for at least 60 assembly cycles.

TABLE 14–2

Cycle time in minutes	*Recommended number of cycles*
0.10	200
0.25	100
0.50	60
0.75	40
1.00	30
2.00	20
2.00– 5.00	15
5.00–10.00	10
10.00–20.00	8
20.00–40.00	5
40.00–above	3

Source: Information taken from the Time Study Manual of the Erie Works of the General Electric Company, developed under the guidance of Albert E. Shaw, manager of wage administration.

Step 6 *Record time data.* Instruct the worker to begin assembling faucets and start the stopwatch. As the worker completes each element, note the elapsed time shown by the stopwatch and record it in the appropriate cell on the Form 7. Note that each cell in the Form 7 is divided into two parts, labeled "R" and "F." The "R" portion is where you should record the elapsed time during the data collection; the "F" portion will be used later. Your data might look like this as you go along:



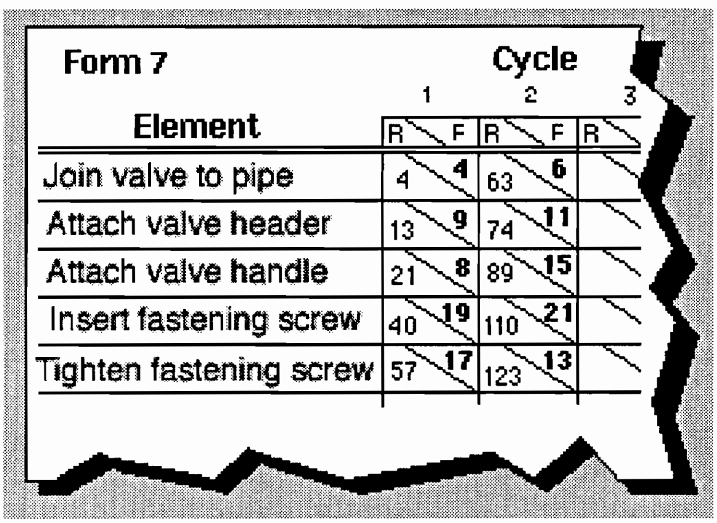
Form 7

Element	Cycle 1 R	Cycle 1 F	Cycle 2 R	Cycle 2 F	Cycle 3 R	Cycle 3 F	Cycle 4 R	Cycle 4 F	Cycle 5 R	Cycle 5 F	Cycle 6 R	Cycle 6 F	Cycle 7 R
Join valve to pipe	4		102										
Attach valve header	13		121										
Attach valve handle	21		150										

Analyzing Time Data

Once you have collected all the time data you need, you must perform some calculations to determine each individual element time and the overall time standard for the faucet assembly operation. This involves three basic steps:

Step 1 *Calculate the individual element times.* To do this, subtract the elapsed time of the preceding element from the elapsed time of the element in question. Then record each element time in the corresponding "F" cell on the Form 7. The figure below illustrates how these calculations are performed and recorded.



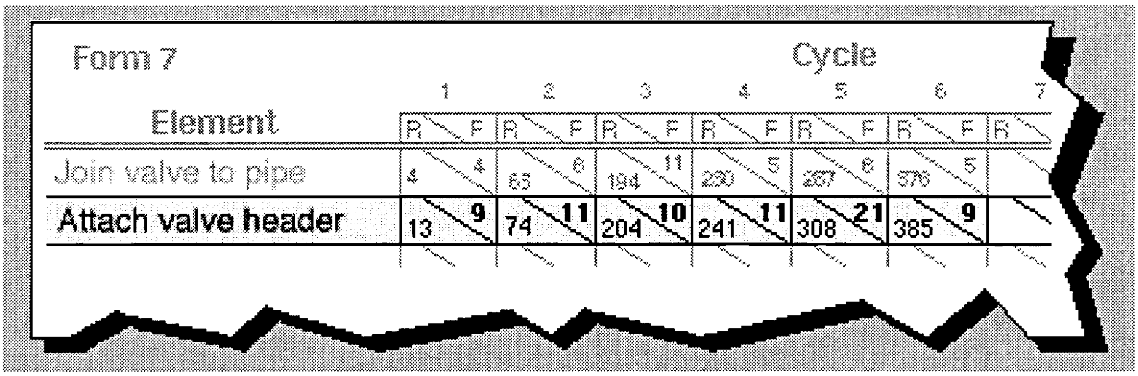
Form 7

Element	Cycle 1 R	Cycle 1 F	Cycle 2 R	Cycle 2 F	Cycle 3 R
Join valve to pipe	4	**4**	63	**6**	
Attach valve header	13	**9**	74	**11**	
Attach valve handle	21	**8**	89	**15**	
Insert fastening screw	40	**19**	110	**21**	
Tighten fastening screw	57	**17**	123	**13**	

Step 2 *Adjust the data set by identifying outliers and discarding them.* An "outlier" is a data point that is so different from the others that it could skew the statistical results. To make sure your results are accurate, you should identify outliers in your time data and discard them. To do this you use a simple statistical test called the Dixon Test.

The Dixon Test is a technique for examining the individual element times you calculated in Step 1. To see how to perform this test, let's go back to our example.

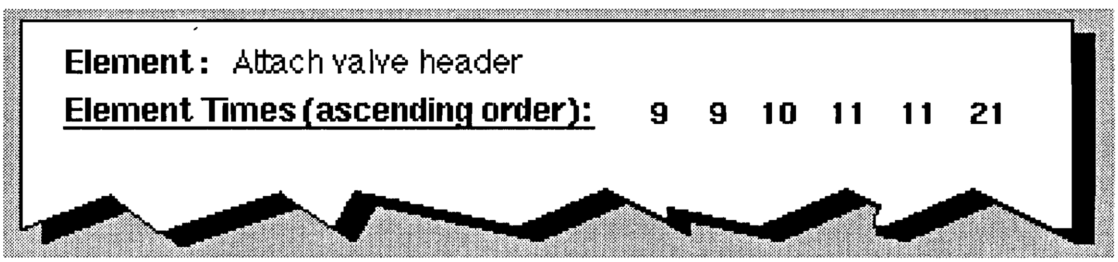
Let's test the data for the second element, "Attach valve assembly securing header." For this example, let's assume that you observed six cycles of the assembly operation.



Form 7

Element	Cycle 1 R	Cycle 1 F	Cycle 2 R	Cycle 2 F	Cycle 3 R	Cycle 3 F	Cycle 4 R	Cycle 4 F	Cycle 5 R	Cycle 5 F	Cycle 6 R	Cycle 6 F	Cycle 7 R
Join valve to pipe	4	4	63	6	194	11	230	5	287	6	376	5	
Attach valve header	13	**9**	74	**11**	204	**10**	241	**11**	308	**21**	385	**9**	

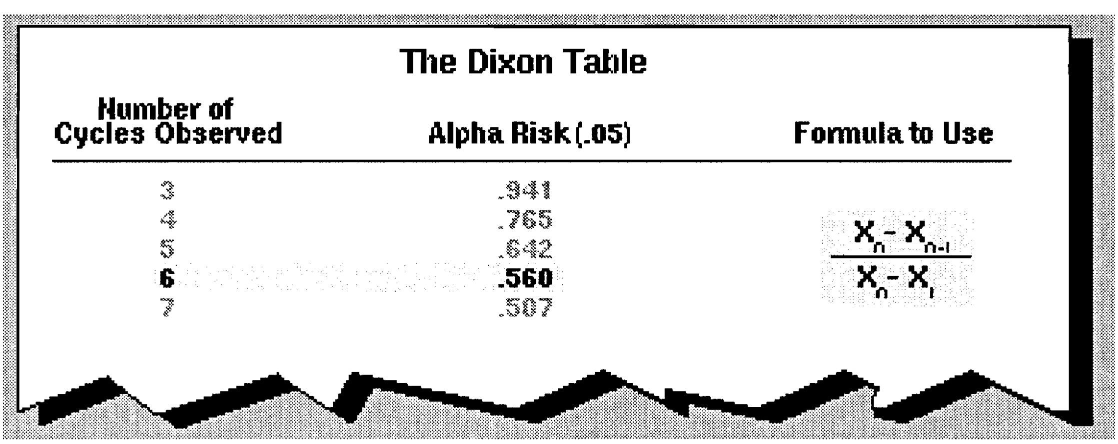
Take the individual element times and list them in ascending order from smallest to largest.



Element: Attach valve header

Element Times (ascending order): **9 9 10 11 11 21**

Begin by looking at the highest and lowest values on your list. Do any look out of place? In this case, the value 21 definitely seems like it doesn't fit. You must determine if 21 is an outlier (if it is, you should discard it from the time data set). To do this, first consult the Dixon Table. It tells you the formula and alpha risk value to use.



The Dixon Table

Number of Cycles Observed	Alpha Risk (.05)	Formula to Use
3	.941	
4	.765	
5	.642	$\frac{X_n - X_{n-1}}{X_n - X_1}$
6	**.560**	
7	.507	

You use the formula to calculate a Dixon value (for the data point 21). Then you compare the Dixon value to the alpha risk value you got from the Dixon Table. If the Dixon value you calculated is equal to or greater than the Table value, you should conclude that 21 *is* an outlier and discard it from the data.

Number of Cycles Observed	Alpha Risk (.05)	Formula to Use
5	.642	
6	**.560**	$\frac{X_n - X_{n-1}}{X_n - X_1}$
7	.507	

The Dixon Test

$$\frac{X_n - X_{n-1}}{X_n - X_1} = \frac{21 - 11}{21 - 9} = .833$$

$.833 \geq .560$

Conclusion: 21 is an outlier

Throw it out!

You should continue performing this test on each element time. Remember, you listed the element times in ascending order. So as soon as you discover that a data point is *not* an outlier, you can stop.

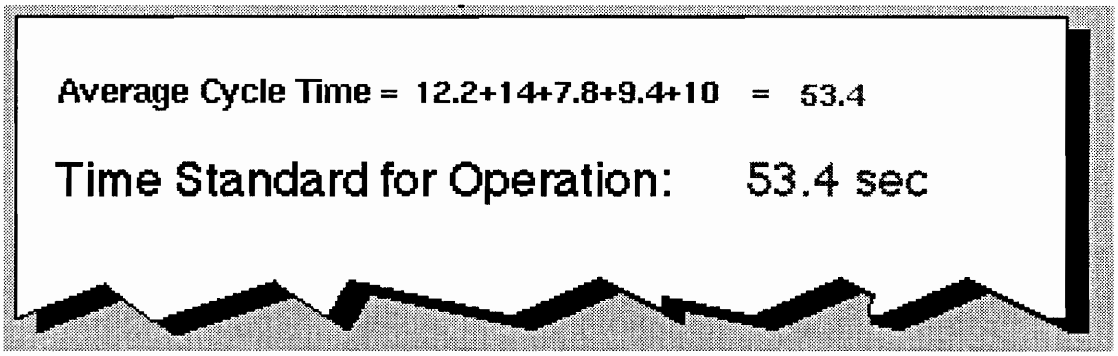
Step 3 *Calculate the average time for each element.* You have eliminated all outliers from the data; from the remaining data points, compute the average time for each element. You should examine these averages to see if there are any elements that take much longer than the others. If so, the operation is probably not as efficient as it could be, and you might look for ways to improve it.

Sum of Element Times: (Unscrew old bulb) **9+9+10+11+11 = 50**

Average Element Time: (Unscrew old bulb) **50/5 = 10.0**

Averaged Element Times: (Other 4 Elements) **12.2, 14.0, 7.8, 9.4**

Step 4 *Calculate the time standard.* To do this, simply add the average element time for all the elements. This time value can now be used as a *standard* for use in a variety of tasks that are essential to the success of any company.



APPENDIX B

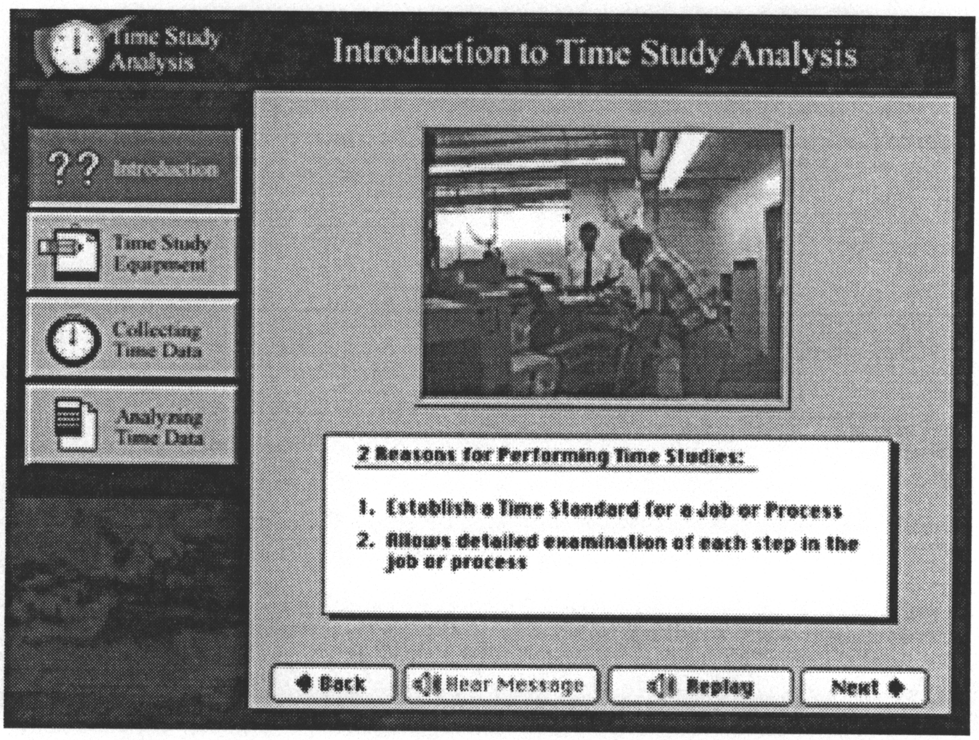
Instructional Treatment 2 (Standard Multimedia)

Instructional Treatment 2: Standard Multimedia

This is a detailed description of the design and layout of instructional treatment 2,(Standard Multimedia). Like the Control Condition, the program was organized into four main topics: (1) Introduction to Time Study Analysis, (2) Time Study Equipment, (3) Collecting Time Data, and (4) Analyzing Time Data. Global buttons (always available) on the screen allowed the learner to select any of these topic areas at any time. This afforded the learner free navigation and backtracking.

In each topic area there was more information presented than could be displayed on a single screen simultaneously. To accommodate this, learners were provided right and left arrow buttons to allow them to flip forward or backward between specific screens of information. There were also two button located between the arrow buttons that gave learners control of playing, replaying, or skipping the sound and/or video/animation segment presented in each specific screen.

The figure below shows a typical screen of information and the universal interface layout



The Program began by presenting the interface *without* the four topic area buttons.

Narrator Voice: "Welcome to a review of Time Study Analysis. These are the four topics you must learn. To select a topic, click on its button.

Display: buttons appear one at a time (synched with voice message)

Topic 1: Introduction to Time Study Analysis

Narrator Voice: "A time study is a work measurement technique used by industrial engineers. It usually requires the engineer (that's you) to observe a worker or workers performing some operation and collect time data. There are two basic reasons that time studies are performed:"

Video: Video clip of I.E. collecting time data (fades out at end)

[next screen]

Narrator Voice: "Performing a time study establishes a time *standard*. A time standard is a formal determination of the amount of time it takes to perform a task or operation *when that job is performed by a normal operator working at a normal pace*. Efficient manufacturing involves many activities, such as production scheduling or cost estimating, for which knowing time standards can be very useful."

Display: Text bullet reinforcing voice message

[next screen]

Narrator Voice: "Performing a time study allows the you to examine the time it takes to complete each element of a task or operation. Most manufacturing tasks or operations require multiple steps, or "elements." If any one element takes much longer to complete than the other elements, then the operation is not being done very efficiently. During a time study you make a record of how long it takes to complete each element of the task so that you can determine if any elements are taking too long. Once the inefficient elements have been discovered, you can make changes to the operation to improve its efficiency."

Display: Text bullet (located below first bullet on same screen) reinforcing voice message

Topic 2: Time Study Equipment

Narrator Voice: "As mentioned earlier, a time study is a measurement technique that involves observing a worker and recording time data. There are four basic items of equipment that you must have to properly record time data."

[next screen]

Narrator Voice: "A stopwatch. They are a common, efficient means of timing an event, and they are simple to understand and operate."

Display: Text bullet reinforcing voice message, alongside small image of stopwatch.

[next screen]

Narrator Voice: "A Form 7 record sheet. The Form 7 is a standard data form that is specifically designed to be used in time studies. It allows you to list all the elements of the operation and record the elapsed time (from the stopwatch) as each element is completed. Once the data collection is finished, you can also record the net time for each element on the Form 7."

Display: Text bullet reinforcing voice message, alongside small image of Form 7.

[next screen]

Narrator Voice: "A time study Board. This is really just a fancy version of a clipboard. It is designed to hold the stopwatch and the Form 7 data sheet."

Display: Text bullet reinforcing voice message, alongside small image of time study board.

[next screen]

Narrator Voice: "A pencil. You'll needs something to record the time data with. A pencil should be used in case you make errors and need to erase."

Display: Text bullet reinforcing voice message, alongside small image of pencil.

Topic 3: Collecting Time Data

Narrator Voice: "Time studies are performed to establish time standards and to examine specific operational elements. The key to both of these functions is raw time data. To see how to collect time data, let's look at an example. Suppose you wanted to perform a time study of a worker assembling a simple faucet. There are six basic steps involved in collecting time data."

Display: still picture of assembled faucet

[next screen]

Narrator Voice: "Step 1: Select an operator to observe. Usually in a manufacturing setting there are many workers performing the same job concurrently, and you must choose only one for data collection. The operator you choose should work at an average pace, neither too fast or too slow. Recall that one reason for doing a time study is to establish a time standard for an operation, and a time standard is a declaration of how long the operation takes the *average* worker to complete working at a *normal* pace."

Display: video clip of several workers working simultaneously. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Narrator Voice: "Step 2: Familiarize yourself with the job. Before you record any time data, it's essential that you watch the worker assemble a few faucets so that you are completely familiar with exactly how he or she does and so that you'll have a rough estimate of the overall cycle time (how long it takes to assemble the faucet from start to finish)."

Display: video clip of hands assembling faucet. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Narrator Voice: "Step 3: Break down the operation into elements. Like most operations, the assembly of the faucet requires several different steps. This blueprint of the faucet shows its different pieces and how they go together.

Display: Animation of blueprint with pieces assembling themselves. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Narrator Voice: "For this example, let's assume you have divided the faucet assembly operation into the following elements: Element 1: Join valve assembly to pipe junction fixture. Element 2: Attach valve assembly securing header. Element 3: Attach valve actuating handle. Element 4: Insert fastening screw. Element 5: Tighten fastening screw."

Display: Bulleted text reinforcing voice message. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Narrator Voice: "Step 4: List the elements on the Form 7 for data recording, like this."

Display: Animation of elements listing themselves on a blank Form . Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Narrator Voice: "Step 5: Determine the number of operational cycles to observe. When the worker completely assembles one faucet, he or she has performed one *cycle* of the operation. To make sure your results are accurate, you must observe and collect time data for a number of cycles. There are set standards for how many cycles should be observed depending on your estimate of the overall cycle time (from Step 2). This table shows exactly how to select the number of cycles to observe based on the overall cycle time estimate. For example, if the faucet assembly operation takes about 30 seconds (or 0.5 minutes) then you should observe and collect time data for at least 60 assembly cycles."

Display: Image of cycles-to-observe with animation of cycle choice highlighting itself. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Narrator Voice: "Step 6: Record time data. Instruct the worker to begin assembling faucets and start the stopwatch. As the worker completes each element, note the elapsed time shown by the stopwatch and record it in the appropriate cell on the Form 7. Note that each cell in the Form 7 is divided into two parts, labeled "R" and "F." The "R" portion is where you should record the elapsed time during the data collection; the "F" portion will be used later. Your data might look like this as you go along:

Display: Video of faucet being assembled. Below that there will be a Form 7 with time data recording itself in the appropriate cells as each element is finished in the video segment. Also list step in bulleted text in upper left corner of presentation area.

Topic 4: Analyzing Time Data

Narrator Voice: "Once you have collected all the time data you need, you must perform some calculations to determine each individual element time and the overall time standard for the faucet assembly operation. This involves three basic steps."

[next screen]

Narrator Voice: "Step 1: Calculate the individual element times. To do this, subtract the elapsed time of the preceding element from the elapsed time of the element in question. Then record each element time in the corresponding "F" cell on the Form 7. The figure below illustrates how these calculations are performed and recorded."

Display: Elapsed times on Form 7 flash and subtraction is performed and displayed in a window adjacent to Form 7. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Narrator Voice: "Step 2: Adjust the data set by identifying outliers and discarding them. An "outlier" is a data point that is so different from the others that it could skew the statistical results. To make sure your results are accurate, you should identify outliers in your time data and discard them. To do this you use a simple statistical test called the Dixon Test. The Dixon Test is a technique for examining the individual element times you calculated in Step 1. To see how to perform this test, let's go back to our example. Let's test the data for the second element, 'Attach valve assembly securing header.' For this example, let's assume that you observed six cycles of the assembly operation. Take the individual element times and list them in ascending order from smallest to largest."

Display: Element times for "attach valve assembly header" move down off sheet and re-order themselves in ascending order on an adjacent sheet. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Narrator Voice: "Begin by looking at the highest and lowest values on your list. Do any look out of place? In this case, the value 21 definitely seems like it doesn't fit. You must determine if 21 is an outlier (if it is, you should discard it from the time data set). To do this, first consult the Dixon Table. It tells you the formula and critical value to use."

Display: Dixon table appears and values and formulas to use highlight themselves (synched with audio).

[next screen]

Narrator Voice: "You use the formula to calculate a Dixon value (for the data point 21). Then you compare the Dixon value to the alpha risk value you got from the Dixon Table. If the Dixon value you calculated is equal to or greater than the Table value, you should conclude that 21 *is* an outlier and discard it from the data."

Display: Animation of Dixon value calculations appears (synched with audio).

[next screen]

Narrator Voice: "You should continue performing this test on each element time. Remember, you listed the element times in ascending order. So as soon as you discover that a data point is *not* an outlier, you can stop."

[next screen]

Narrator Voice: "Step 3: Calculate the average time for each element. You have eliminated all outliers from the data; from the remaining data points, compute the average time for each element. You should examine these averages to see if there are any elements that take much longer than the others. If so, the operation is probably not as efficient as it could be, and you might look for ways to improve it."

Display: Animation of sample calculations. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Narrator Voice: "Step 4: Calculate the time standard. To do this, simply add the average element time for all the elements. This time value can now be used as a *standard* for use in a variety of tasks that are essential to the success of any company."

Display: Animation of sample calculations. Also list step in bulleted text in upper left corner of presentation area.

APPENDIX C

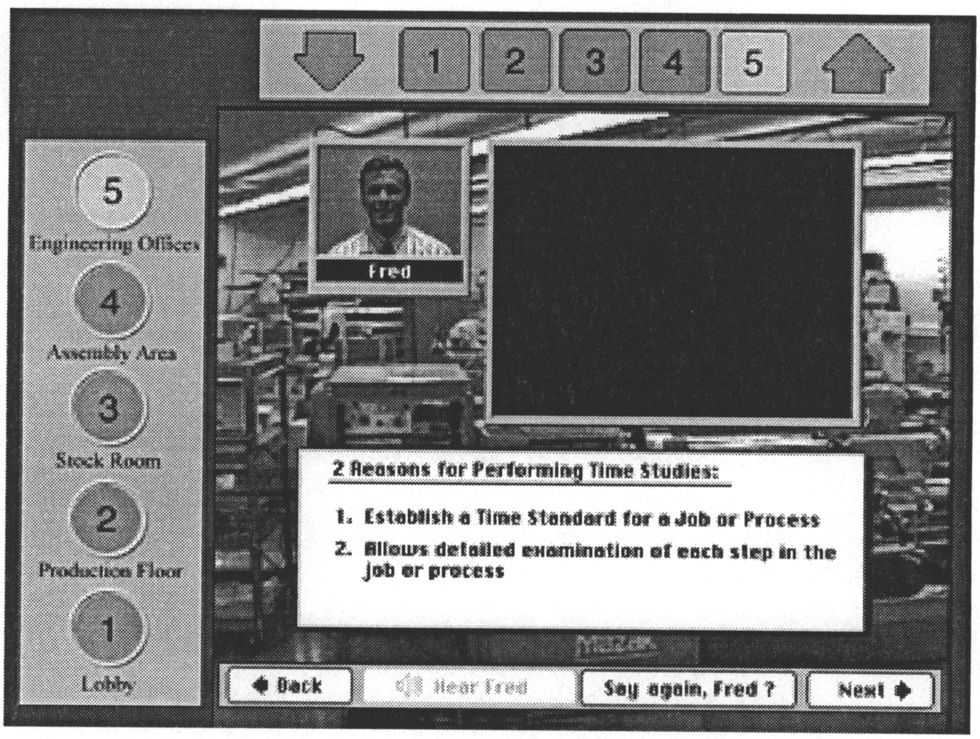
Instructional Treatment 3 (Multimedia Simulation)

Instructional Treatment 3: Multimedia Simulation

This is a detailed description of the design and layout of instructional treatment 3 (multimedia simulation). It presented the same material as is presented in the Control Condition (Appendix A) and in the Standard Multimedia (Appendix B). The program was organized into four main destinations (topics): (1) Engineering Offices (Introduction to Time Study Analysis), (2) The Production Floor (Time Study Equipment), (3) The Assembly Area (Collecting Time Data), and (4) Back to Engineering Offices (Analyzing Time Data). Global buttons (always available) on the screen allowed the learner to select any of these topic areas at any time. This afforded the learner free navigation and backtracking.

In each topic area there was more information presented than could be displayed on a single screen simultaneously. To accommodate this, learners were provided right and left arrow buttons to allow them to flip forward or backward between specific screens of information. There were also two button located between the arrow buttons that gave learners control of playing, replaying, or skipping the sound and/or video/animation segment presented in each specific screen.

The figure below shows a typical screen of information and the universal interface layout



The Program began by displaying images of the ACME plant (from outside) and the outside of an elevator. The elevator spoke to learners to introduce them to the setting.

Elevator Voice: "Welcome to ACME Faucet Corporation. You are starting your first day on the job as an industrial engineer. Right now you are on the first floor--lobby. Please report to the Engineering offices on the fifth floor."

[Learner selects 5th floor--Engineering Offices. Elevator door closes, lights indicate motion upward to 5th floor.]

Elevator Voice: "Fifth floor--Engineering Offices."

Topic 1: Engineering Offices (Introduction)

Setting: Engineering offices serve as background image. Image of Fred (industrial engineering co-worker) appears.

Fred: "Welcome to the ACME Faucet Corporation! My name's Fred, and since this is your first day on the job, I'm going to take you around and show you how things work around here. Your job her at ACME will be to perform time studies on many of our manufacturing operations. We build lots of different kinds of faucets, and one of the most important things we do is perform time studies so that we always know exactly how things are working and how long production is taking. The first thing I'd like to do today is take you down to the production floor to show you a little bit about time studies and you can see first-hand how they're performed."

[Learner selects 2nd floor--Production Floor. Elevator door closes, lights indicate motion downward to 2nd floor.]

Elevator Voice: "Second floor--Production floor."

Fred: "Here on the shop floor you can see that Bob over there is collecting some time data. He's watching ol' Charlie doing some careful machining. A time study is basically a work measurement technique used often by industrial engineers. There are two main reasons that time studies are performed. "

Display: Video of worker doing job while an engineer collects time data. Text bullet reinforcing voice message

[next screen]

Boss: "Performing a time study establishes a time *standard*. A time standard is a formal determination of the amount of time it takes to perform a task or operation *when that job is performed by a normal operator working at a normal pace*. Efficient manufacturing involves many activities, such as production scheduling or cost estimating, for which knowing time standards can be very useful."

Display: Video of worker doing job while an engineer collects time data. Text bullet reinforcing voice message

[next screen]

Fred: "Performing a time study also allows the you to examine the time it takes to complete each element of a task or operation. Most manufacturing tasks or operations require multiple steps, or "elements." If any one element takes much longer to complete than the other elements, then the operation is not being done very efficiently. During a time study you make a record of how long it takes to complete each element of the task so that you can determine if any elements are taking too long. Once the inefficient elements have been discovered, you can make changes to the operation to improve its efficiency."

Display: Video of worker doing job while an engineer collects time data. Text bullet reinforcing voice message

[next screen]

Fred: "Now that you know why we do time studies, let's see how to do a time study. You might have noticed that Bob was using some equipment to collect time data. Let's go to the stockroom now so I can show you what equipment is required when you're collecting time data."

[Learner selects 3rd floor--Stockroom. Elevator door closes, lights indicate motion upward to 3rd floor.]

Elevator Voice: "Third floor--Stockroom."

Topic 2: The Stockroom (Time Study Equipment)

Setting: Picture of stockroom is background image.

Fred: "As mentioned earlier, a time study is a measurement technique that involves observing a worker and recording time data. There are four basic items of equipment that you must have to properly record time data. So, we've come to the stockroom to get that equipment."

[next screen]

Fred: "First you need a stopwatch. They are a common, efficient means of timing an event, and they are simple to understand and operate."

Display: Text bullet reinforcing voice message, alongside small image of stopwatch.

[next screen]

Fred: "Next you need a Form 7 record sheet. The Form 7 is a standard data form that is specifically designed to be used in time studies. It allows you to list all the elements of the operation and record the elapsed time (from the stopwatch) as each element is completed. Once the data collection is finished, you can also record the net time for each element on the Form 7."

Display: Text bullet reinforcing voice message, alongside small image of Form 7.

[next screen]

Fred: "Then you'll need a time study Board. This is really just a fancy version of a clipboard. It is designed to hold the stopwatch and the Form 7 data sheet."

Display: Text bullet reinforcing voice message, alongside small image of time study board.

[next screen]

Fred: "Finally you'll need a pencil. You'll needs something to record the time data with. A pencil should be used in case you make errors and need to erase."

Display: Text bullet reinforcing voice message, alongside small image of pencil.

[next screen]

Fred: "OK, you've seen all the equipment you'll need for recording time data. Now, let's take a closer look at how to collect actual time data. Let's go to the Assembly Area where we'll find workers performing an assembly operation that we can examine as an example in performing a time study."

[Learner selects 4th floor--Assembly Area. Elevator door closes, lights indicate motion upward to 4th floor.]

Elevator Voice: "Fourth floor--Assembly Area"

Topic 3: The Assembly Area (Collecting Time Data)

Setting: Picture of Assembly Area is background image.

Fred: "The Production Floor is where many operations take place, so it's a good place for us to look at an operation to see how to collect actual time data. Let's look at a simple faucet assembly operation. There are six basic steps in collecting raw time data."

Display: still picture of assembled faucet with list appearing to hold bulleted text.

[next screen]

Fred: "Step 1 is to select an operator to observe. Here at ACME there are always teams of workers performing assembly, so you must choose just one to observe. Here you see Charlie agreeing to help Bob with his time data collection. Bob has selected Charlie because he always works at a normal pace, neither too fast nor too slow."

Display: video clip of several workers working simultaneously. Then worker and engineer come together to shake hands. Also list step in bulleted text.

[next screen]

Fred: "Step 2 is to familiarize yourself with the assembly operation. Here we see Charlie as he assembles a faucet. You should watch him assemble several faucets before collecting any time data, so that you know how he does it, and also so that you can get a rough estimate of the overall cycle time. "

Display: video clip of hands assembling faucet. Also list step in bulleted text.

[next screen]

Fred: "Step 3: Break down the operation into elements. Like most operations, the assembly of the faucet requires several different steps. This blueprint of the faucet shows its different pieces and how they go together.

Display: Animation of blueprint with pieces assembling themselves. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Fred: "For this example, let's assume you have divided the faucet assembly operation into the following elements: Element 1: Join valve assembly to pipe junction fixture. Element 2: Attach valve assembly securing header. Element 3: Attach valve actuating handle. Element 4: Insert fastening screw. Element 5: Tighten fastening screw."

Display: Bulleted text reinforcing voice message. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Fred: "Step 4: List the elements on the Form 7 for data recording, like this."

Display: Animation of elements listing themselves on a blank Form . Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Fred: "Step 5: Determine the number of operational cycles to observe. When the worker completely assembles one faucet, he or she has performed one *cycle* of the operation. To make sure your results are accurate, you must observe and collect time data for a number of cycles. There are set standards for how many cycles should be observed depending on your estimate of the overall cycle time (from Step 2). This table shows exactly how to select the number of cycles to observe based on the overall cycle time estimate. For example, if the faucet assembly operation takes about 30 seconds (or 0.5 minutes) then you should observe and collect time data for at least 60 assembly cycles."

Display: Image of cycles-to-observe with animation of cycle choice highlighting itself. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Fred: "Finally, step 6 is to record the time data. As Charlie assembles each faucet, watch for when he completes each of the job elements. As he does, record the time the stopwatch reads in the "R" portion of the appropriate cell on the Form 7. Don't worry about the "F" portion for right now--it will be used later."

Display: Video of faucet being assembled. Next to video a Form 7 appears with time data recording itself in the appropriate cells as each element is finished in the video segment. Also list step in bulleted text.

[next screen]

Fred: "Now we've seen how to collect raw time data for our time study. In order to figure out our time standard, we need to do some simple analysis of our time data. Let's go back to my office where we can sit down with a calculator and I can show you how to work out the time standard."

[Learner selects 5th floor--Engineering Offices. Elevator door closes, lights indicate motion upward to 5th floor.]

Elevator Voice: "Fifth floor--Engineering Offices."

Topic 4: Engineering Offices (Analyzing Time Data)

setting: Engineering Offices (same as in topic 1)

Fred: "OK, now I'll explain how to analyze our time data. This analysis involves four basic steps:"

[next screen]

Fred: "Step 1: Calculate the individual element times. To do this, subtract the elapsed time of the preceding element from the elapsed time of the element in question. Then record each element time in the corresponding "F" cell on the Form 7. The figure below illustrates how these calculations are performed and recorded."

Display: Elapsed times on Form 7 flash and subtraction is performed and displayed in a window adjacent to Form 7. Also list step in bulleted text.

[next screen]

Fred: "Step 2: Adjust the data set by identifying outliers and discarding them. An "outlier" is a data point that is so different from the others that it could skew the statistical results. To make sure your results are accurate, you should identify outliers in your time data and discard them. To do this you use a simple statistical test called the Dixon Test. The Dixon Test is a technique for examining the individual element times you calculated in Step 1. To see how to perform this test, let's go back to our example. Let's test the data for the second element, 'Attach valve assembly securing header.' For this example, let's assume that you observed six cycles of the assembly operation. Take the individual element times and list them in ascending order from smallest to largest."

Display: Element times for "attach valve assembly header" move down off sheet and re-order themselves in ascending order on an adjacent sheet. Also list step in bulleted text.

[next screen]

Fred: "Begin by looking at the highest and lowest values on your list. Do any look out of place? In this case, the value 21 definitely seems like it doesn't fit. You must determine if 21 is an outlier. To do this, first consult the Dixon table. It tells you the formula and critical value to use."

Display: Dixon table appears and values and formulas to use highlight themselves (synched with audio).

[next screen]

Fred: "You use the formula to calculate a Dixon value for the data point 21. Then you compare your Dixon value to the critical value you got from the Dixon table. If your Dixon value is equal to or greater than your critical value, you should conclude that 21 is an outlier and discard it from the data."

Display: Animation of Dixon value calculations appears (synched with audio).

[next screen]

Fred: "You should continue performing this test on each element time. Remember, you listed the element times in ascending order. So as soon as you discover that a data point is *not* an outlier, you can stop."

[next screen]

Fred: "Step 3: Calculate the average time for each element. You have eliminated all outliers from the data; from the remaining data points, compute the average time for each element. You should examine these averages to see if there are any elements that take much longer than the others. If so, the operation is probably not as efficient as it could be, and you might look for ways to improve it."

Display: Animation of sample calculations. Also list step in bulleted text.

[next screen]

Fred: "Step 4: Calculate the time standard. To do this, simply add the average element time for all the elements. This time value can now be used as a *standard* for use in a variety of tasks that are essential to the success of any company."

Display: Animation of sample calculations. Also list step in bulleted text.

[next screen]

Fred: "OK, the time standard we calculated is the answer we're looking for. It will be invaluable in all sorts of production-related tasks. You've done a great job today, and I'm real proud of you!

APPENDIX D

Experimental Post-test

Introduction to Time Study Analysis -- Post-Instructional Test

Part 1: Short Answer

When you have completed each page return it to the experimenter to receive the next question or set of questions.

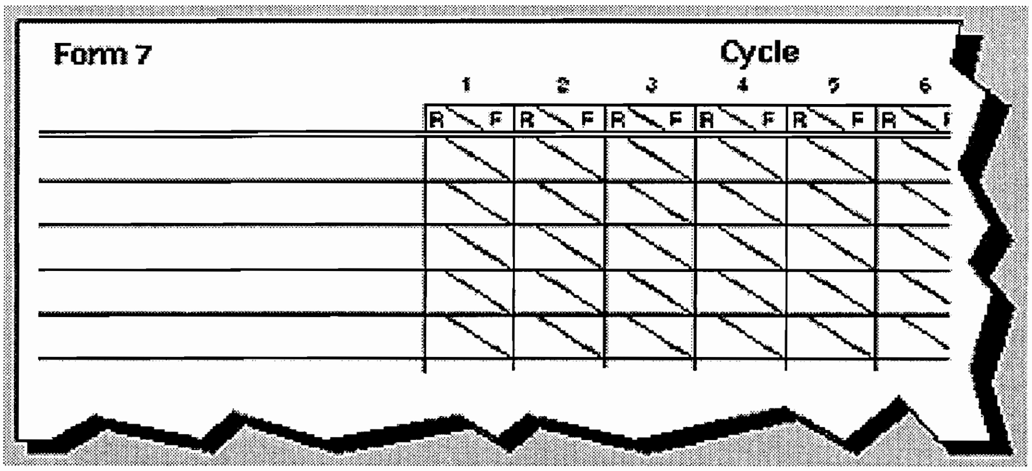
There are two main reasons for performing a time study. What are they?

What is the definition of a *time standard*?

One of the reasons for performing a time study is to establish a time standard for a job or process. How are time standards useful to a company? Provide one example.

Performing a time study involves collecting time data. There are four basic items of equipment used to collect time data. What are they?

Below is a sample Form 7 data sheet for recording time data. Label the following parts: cells for listing job elements, cells for recording net element times, and cells for recording elapsed times .



Introduction to Time Study Analysis -- Post-Instructional Test

Part 2: Multiple-Choice

When choosing a worker to observe for a time study, what quality should that worker possess that makes him or her a good choice?

A. He or she should be fast and highly efficient so that time data will be as accurate as possible.

B. He or she should be just average and work only at a normal speed.

C. He or she should be the senior-most operator since he or she will be the most familiar with all the intricacies of the job being studied.

D. He or she should be just average but should work as fast as possible when time data is being collected.

E. He or she should be selected only if recommended by a foreman or supervisor.

Before collecting time data, how would you determine the minimum number of operational cycles to observe?

A. Discuss it with the operator you have chosen to observe, since he or she is the real expert on how the job is done.

B. Discuss it with shop floor supervisors to get their opinion, since a mistrustful operator could deliberately mislead you.

C. Start by picking a number arbitrarily; if you discover later that you need more data you can go back and record additional times.

D. There is a standard table showing the minimum number of cycles to observe based on the estimated overall cycle time.

E. There is no requirement for a minimum number of cycles to observe.

There are six basic steps involved in collecting time data for a time study. They are (in order):

A. (1) select a worker to observe, (2) familiarize yourself with the job, (3) break down the job into individual elements, (4) list individual job elements on the Form 7 data sheet, (5) determine the minimum number of cycles to observe, and (6) record the time data.

B. (1) determine the minimum number of cycles to observe, (2) select a worker to observe, (3) familiarize yourself with the job, (4) break down the job into individual elements, (5) list individual job elements on the Form 7 data sheet, and (6) record the time data.

C. (1) select a worker to observe, (2) break down the job into individual elements, (3) list individual job elements on the Form 7 data sheet, (4) familiarize yourself with the job, (5) determine the minimum number of cycles to observe, and (6) record the time data.

D. (1) familiarize yourself with the job, (2) break down the job into individual elements, (3) list individual job elements on the Form 7 data sheet, (4) select a worker to observe, (5) determine the minimum number of cycles to observe, and (6) record the time data.

E. (1) break down the job into individual elements, (2) list individual job elements on the Form 7 data sheet, (3) familiarize yourself with the job, (4) select a worker to observe, (5) determine the minimum number of cycles to observe, and (6) record the time data.

Once time data has been collected, it must be analyzed. There are four basic steps in analyzing time data. They are (in order):

A. (1) adjust the data for outliers using the Dixon Test, (2) calculate the individual element times, (3) calculate each average element time, and (4) calculate the time standard.

B. (1) adjust the data for outliers using the Dixon Test, (2) calculate each average element time, (3) calculate the individual element times, and (4) calculate the time standard.

C. (1) calculate the individual element times, (2) list those element times in ascending order, (3) adjust the data for outliers using the Dixon Test, and (4) calculate the time standard.

D. (1) list the element times in ascending order, (2) adjust the data for outliers using the Dixon Test, (3) calculate each average element time, and (4) calculate the time standard.

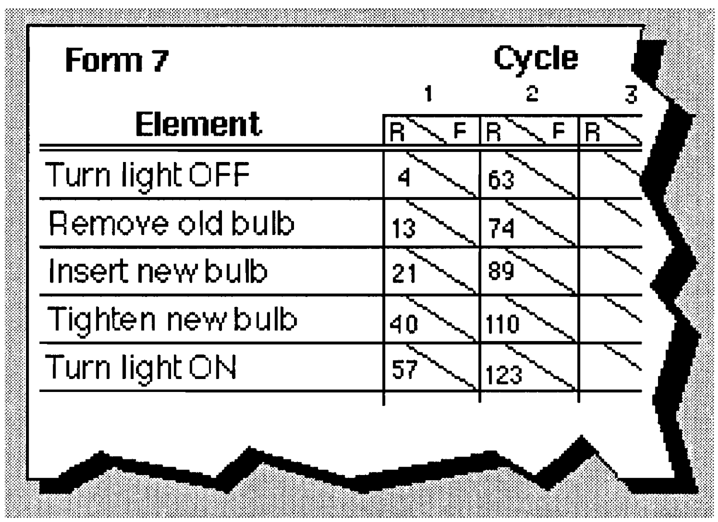
E. (1) calculate the individual element times, (2) adjust the data for outliers using the Dixon Test, (3) calculate each average element time, and (4) calculate the time standard.

Introduction to Time Study Analysis -- Post-Instructional Test

Part 3: Problem-Solving

You may use the calculator and any tables or figures provided to aid you in solving each problem. Please show all your work, since your method and approach to solving the problem is just as important as coming up with the correct answer.

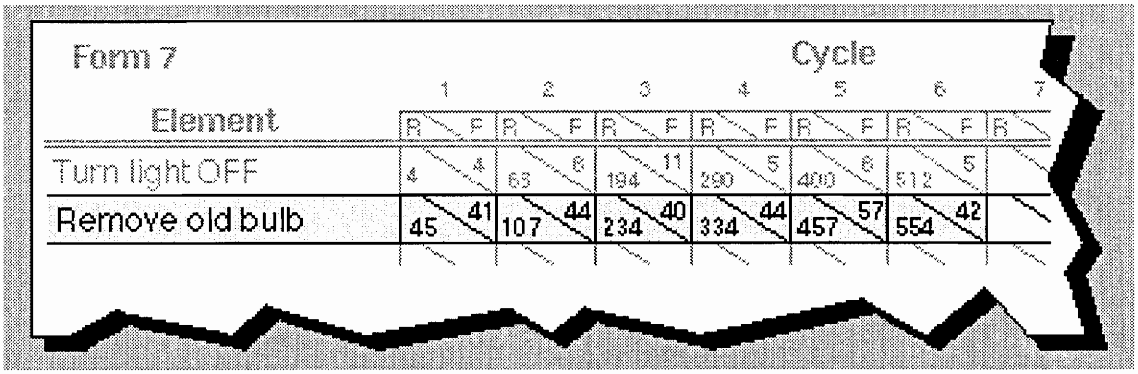
Suppose you performed a time study on the operation of changing a light bulb. The figure below shows a sample set of time data for 2 cycles of the job. Calculate the individual element times and record them in the appropriate cells on the Form 7.



Form 7

Element	Cycle 1 R	Cycle 1 F	Cycle 2 R	Cycle 2 F	Cycle 3 R	Cycle 3 F
Turn light OFF	4		63			
Remove old bulb	13		74			
Insert new bulb	21		89			
Tighten new bulb	40		110			
Turn light ON	57		123			

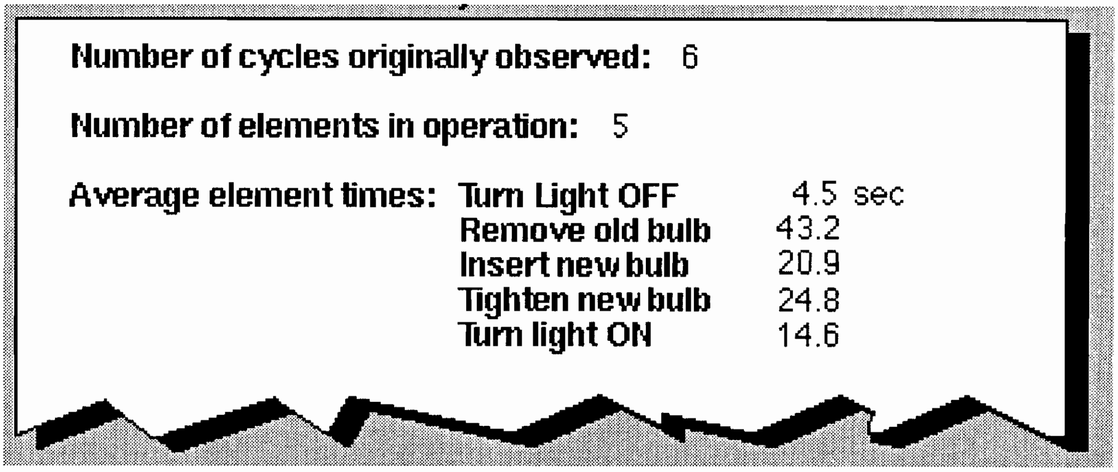
Suppose for the light bulb changing operation that your time data and corresponding element times look as shown in the figure below.



Form 7	Cycle 1 R	Cycle 1 F	Cycle 2 R	Cycle 2 F	Cycle 3 R	Cycle 3 F	Cycle 4 R	Cycle 4 F	Cycle 5 R	Cycle 5 F	Cycle 6 R	Cycle 6 F	Cycle 7 R
Element	R	F	R	F	R	F	R	F	R	F	R	F	R
Turn light OFF	4	4	63	6	194	11	290	5	400	6	512	5	
Remove old bulb	45	41	107	44	234	40	334	44	457	57	554	42	

For the element called "Remove old bulb" identify any outliers and adjust your data set accordingly.

Suppose for the light bulb changing operation that you have correctly adjusted your time data to eliminate all outliers. Now suppose that you have correctly calculated the average element time for all five individual elements of the job as shown below. Calculate the time standard for the entire job.



APPENDIX E

Guidelines for "Degree of Correctness" for Post-test Grading

Post-instructional Test
Answer Key and Guidelines for "Degree of Correctness"

Part 1: Short Answer

There are two main reasons for performing a time study. What are they? *(12 possible points)*

6 points awarded if subject responded "to establish a time standard" or something to that effect. 3 points awarded if response included something about "average time to complete a process" but did not specify a "time standard."

6 points if subject responded "to examine operational elements of a job or process to look for possible methods improvements. 3 points awarded if response discussed examining a job or process but was not extended to say "for the purpose of possibly making methods improvements."

What is the definition of a *time standard*? *(12 possible points)*

3 points awarded automatically

3 points awarded if response included statement of "average time to complete a job or process" or something to that effect.

3 points awarded if response stated time for a "normal operator" to complete a job or process

3 points awarded if response included time for operator to complete a job or process "working at a normal pace" or something to that effect.

One of the reasons for performing a time study is to establish a time standard for a job or process. How are time standards useful to a company? Provide one example. *(12 possible points)*

3 points awarded automatically

6 points awarded if response included statement of "time standards aid in many manufacturing-related tasks and jobs" or something to that effect.

3 points awarded for any correct example, such as "production scheduling or cost estimating."

Performing a time study involves collecting time data. There are four basic items of equipment used to collect time data. What are they? *(12 possible points)*

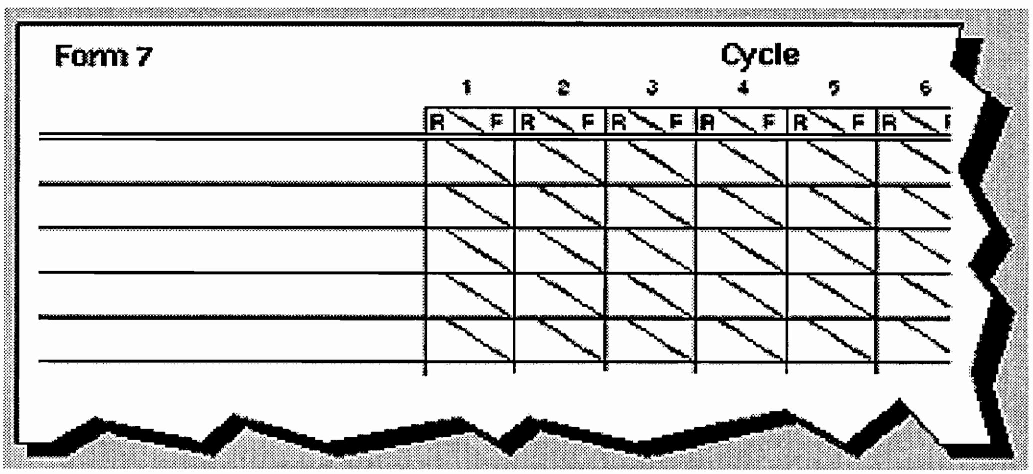
3 points awarded for "stopwatch"

3 points awarded for "Form 7" or variations such as "sheet 7" or "data record 7"

3 points awarded for "time study board" or variations provided the variation specified that the board held both the data recording sheet and the stopwatch together

3 points awarded for "pencil"

Below is a sample Form 7 data sheet for recording time data. Label the following parts: cells for listing job elements, cells for recording net element times, and cells for recording elapsed times . *(12 possible points)*



3 points awarded automatically

3 points awarded for correcting identifying and labeling cells for listing job elements

3 points awarded for correcting identifying and labeling cells for recording elapsed times from the stopwatch during data collection

3 points awarded for correcting identifying and labeling cells for recording net element times during data analysis

Introduction to Time Study Analysis -- Post-Instructional Test

Part 2: Multiple-Choice

When choosing a worker to observe for a time study, what quality should that worker possess that makes him or her a good choice?

A. He or she should be fast and highly efficient so that time data will be as accurate as possible.

B. He or she should be just average and work only at a normal speed.

C. He or she should be the senior-most operator since he or she will be the most familiar with all the intricacies of the job being studied.

D. He or she should be just average but should work as fast as possible when time data is being collected.

E. He or she should be selected only if recommended by a foreman or supervisor.

B. He or she should be just average and work only at a normal speed.

Before collecting time data, how would you determine the minimum number of operational cycles to observe?

A. Discuss it with the operator you have chosen to observe, since he or she is the real expert on how the job is done.

B. Discuss it with shop floor supervisors to get their opinion, since a mistrustful operator could deliberately mislead you.

C. Start by picking a number arbitrarily; if you discover later that you need more data you can go back and record additional times.

D. There is a standard table showing the minimum number of cycles to observe based on the estimated overall cycle time.

E. There is no requirement for a minimum number of cycles to observe.

D. There is a standard table showing the minimum number of cycles to observe based on the estimated overall cycle time.

There are six basic steps involved in collecting time data for a time study. They are (in order):

A. (1) select a worker to observe, (2) familiarize yourself with the job, (3) break down the job into individual elements, (4) list individual job elements on the Form 7 data sheet, (5) determine the minimum number of cycles to observe, and (6) record the time data.

B. (1) determine the minimum number of cycles to observe, (2) select a worker to observe, (3) familiarize yourself with the job, (4) break down the job into individual elements, (5) list individual job elements on the Form 7 data sheet, and (6) record the time data.

C. (1) select a worker to observe, (2) break down the job into individual elements, (3) list individual job elements on the Form 7 data sheet, (4) familiarize yourself with the job, (5) determine the minimum number of cycles to observe, and (6) record the time data.

D. (1) familiarize yourself with the job, (2) break down the job into individual elements, (3) list individual job elements on the Form 7 data sheet, (4) select a worker to observe, (5) determine the minimum number of cycles to observe, and (6) record the time data.

E. (1) break down the job into individual elements, (2) list individual job elements on the Form 7 data sheet, (3) familiarize yourself with the job, (4) select a worker to observe, (5) determine the minimum number of cycles to observe, and (6) record the time data.

A. (1) select a worker to observe, (2) familiarize yourself with the job, (3) break down the job into individual elements, (4) list individual job elements on the Form 7 data sheet, (5) determine the minimum number of cycles to observe, and (6) record the time data.

Once time data has been collected, it must be analyzed. There are four basic steps in analyzing time data. They are (in order):

A. (1) adjust the data for outliers using the Dixon Test, (2) calculate the individual element times, (3) calculate each average element time, and (4) calculate the time standard.

B. (1) adjust the data for outliers using the Dixon Test, (2) calculate each average element time, (3) calculate the individual element times, and (4) calculate the time standard.

C. (1) calculate the individual element times, (2) list those element times in ascending order, (3) adjust the data for outliers using the Dixon Test, and (4) calculate the time standard.

D. (1) list the element times in ascending order, (2) adjust the data for outliers using the Dixon Test, (3) calculate each average element time, and (4) calculate the time standard.

E. (1) calculate the individual element times, (2) adjust the data for outliers using the Dixon Test, (3) calculate each average element time, and (4) calculate the time standard.

E. (1) calculate the individual element times, (2) adjust the data for outliers using the Dixon Test, (3) calculate each average element time, and (4) calculate the time standard.

Introduction to Time Study Analysis -- Post-Instructional Test

Part 3: Problem-Solving

You may use the calculator and any tables or figures provided to aid you in solving each problem. Please show all your work, since your method and approach to solving the problem is just as important as coming up with the correct answer.

Suppose you performed a time study on the operation of changing a light bulb. The figure below shows a sample set of time data for 2 cycles of the job. Calculate the individual element times and record them in the appropriate cells on the Form 7. *(25 possible points)*

Form 7

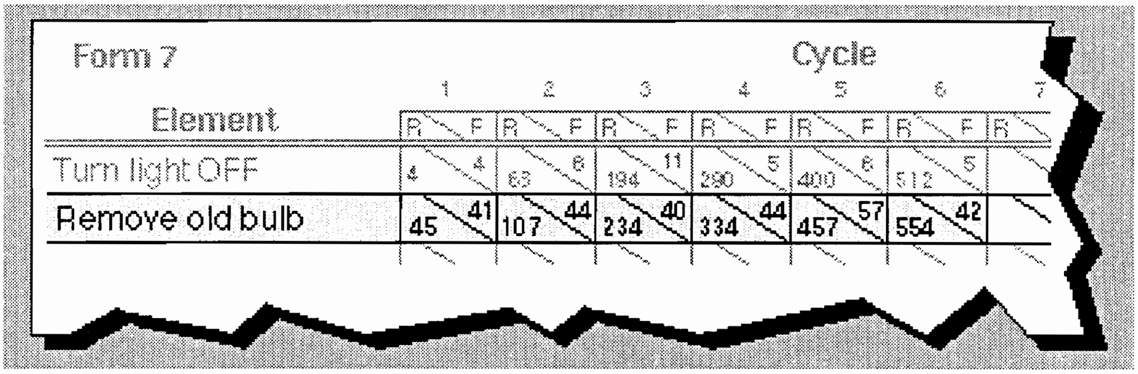
Element	Cycle 1 R	Cycle 1 F	Cycle 2 R	Cycle 2 F	Cycle 3 R
Turn light OFF	4		63		
Remove old bulb	13		74		
Insert new bulb	21		89		
Tighten new bulb	40		110		
Turn light ON	57		123		

10 points awarded for displaying through shown work correct knowledge of the proper procedure

10 points awarded for correcting listing element times in appropriate cells

5 points awarded for determining the correct numerical answers

Suppose for the light bulb changing operation that your time data and corresponding element times look as shown in the figure below.



For the element called "Remove old bulb" identify any outliers and adjust your data set accordingly. *(25 possible points)*

5 points awarded for properly listing element times in ascending order

5 points awarded for selecting correct Dixon formula to use (from formula sheet provided by experimenter during testing)

5 points awarded for using proper procedure (beginning with extreme values and testing)

5 points awarded for correctly applying the Dixon formula chosen

5 points awarded for determining the correctly adjusted data set

From your adjusted data set, calculate the average time to complete the element "Remove old bulb."

10 points awarded for demonstrating calculation procedure

10 points awarded for properly using the data in calculations (even if adjusted data set was incorrect)

5 points awarded for determining the correct average time (based on whatever data set was used from previous question)

Suppose for the light bulb changing operation that you have correctly adjusted your time data to eliminate all outliers. Now suppose that you have correctly calculated the average element time for all five individual elements of the job as shown below. Calculate the time standard for the entire job. *(25 possible points)*

Number of cycles originally observed: 6

Number of elements in operation: 5

Average element times:	**Turn Light OFF**	4.5 sec
	Remove old bulb	43.2
	Insert new bulb	20.9
	Tighten new bulb	24.8
	Turn light ON	14.6

5 points awarded automatically

10 points awarded for demonstrating proper calculation procedure

10 points awarded for determining the correct time standard

APPENDIX F

Subject Screening Questionnaire

Subject Screening Questionnaire

Have you ever had exposure to, or experience with, computer-based multimedia programs?

Have you ever taken a course in, or had other experience with work methods engineering or other related principles?

Have you ever had exposure to, or experience with, performing time studies?

Thank you.

APPENDIX G

Informed Consent Form

Participant's Informed Consent Form

Title of Project: Simulating User Experiences in Computer-based Multimedia Instruction

Principal Investigator: Dr. R. C. Williges

Purpose of the Research Project

You are invited to participate in a study about the relative effectiveness of different methods of instruction. This study involves experimentation for the purpose of determining whether human learners will benefit from this instruction.

Procedures

You will be given a set of instructional materials and asked to review them as though you were studying for a test. Indeed, when you have finished reviewing the instruction, you will be asked to complete a short test to see how much you have learned.

There are no foreseeable risks to you as a participant. Thus, no safeguards have been established.

Benefits of this Project

Your participation will be helpful in determining the relative effectiveness of the instructional materials. While you may find the experiment interesting and/or informative, there are no direct benefits to you as a participant. No guarantee of benefits has been made to encourage you to participate.

You may receive a synopsis or summary of this research when completed. If you so desire, provide the experimenter with a self-addressed, stamped envelope.

Anonymity and Confidentiality

The results of this study will be kept strictly confidential. At no time will the researchers release the results of the study to anyone other than the individuals working on the project without your written consent. The information you provide will have your name removed and only a subject number will identify you during analyses and any written reports of the research.

Compensation

For your participation you will receive $5 per hour.

Freedom to Withdraw

You are free to withdraw from this study at any time without penalty. If you choose to withdraw, you will be compensated for the portion of the study during which you participated.

If the investigator determines from the pre-study questionnaire that you are ineligible to participate, you will be compensated for the portion of the experiment completed.

Approval of Research

This project has been approved, as required by the Institutional Review Board for projects involving human subjects at Virginia Polytechnic Institute and State University, and by the Department of Industrial and Systems Engineering.

Subject's Responsibilities

I know of no reason I cannot participate in this study.

____

Signature

Subject's Permission

I have read and understand the informed consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this research.

If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.

Should I have any questions about this research or its conduct, I will contact:

Carl Petitt, graduate student (703) 951-1418

Dr. Robert Williges, Virginia Tech Faculty Member (703) 231-6270

Ernest Stout, Chair, IRB Research Division (703) 231-9359

APPENDIX H

Experimental Overview and Instructions

Instructional System Research

Instructions

Thank you for agreeing to participate in this experiment. This study is being conducted in the Human Computer Interaction Laboratory of the Human Factors Engineering Center at Virginia Tech. The experiment is being conducted by Carl Petitt under the supervision of Dr. Robert Williges, a professor in Industrial and Systems Engineering.

The purpose of this study is to compare the effectiveness of several different instructional systems. As an experimental subject you will serve as the learner and you will engage in one-on-one instruction with an instructional system.

The subject material you will be taught consists of some basic fundamentals of performing a work measurement technique called Time Study Analysis. You will have a set amount of time in which to engage in this instruction, and then the instruction will be removed and you will be tested to see what you have learned.

The experiment will take approximately one hour, and you will be paid $5 per hour for your participation. Once you have read this sheet and signed the informed consent form you will be ready for the experiment. You will have a maximum of 30 minutes to go through the instruction. You will be monitored during the instruction by the experimenter.

It is important that you keep in mind that you will be tested afterward, so you should treat the experimental situation as though you were studying for any normal test for class. You will be tested on the principles and procedures of choosing to perform a time study, pre-data collection activities, and methods of data collection and analysis.

The data will be analyzed after all data has been collected. The results can be made available to you if you wish to review them.

Thank you again for participating in this experiment. If you have ANY questions don't hesitate to ask them. It is important that you fully understand everything involved in the study so that it can go as smoothly as possible.

VITA

Carlton Sutherland Petitt was born in Atlanta, Georgia on March 20, 1969. He earned a Bachelors degree in Industrial and Systems Engineering from Virginia Polytechnic Institute and State University in 1992. During his high school years in Atlanta and college years in Virginia he held positions with or worked on projects for Lockheed Aerospace Corporation, Donnkenny Apparel Manufacturing and Distribution, Management Systems Laboratories, The Virginia Tech Ergonomics Laboratory, Litton Industries-Poly Scientific, and most recently the Multimedia Lab at Virginia Tech. In September 1994 he earned a Masters degree in Human Factors Engineering from Virginia Tech.

Carl is currently a member of the Corporate Technology Group at the American Management Systems Center for Advanced Technologies in Fairfax, Virginia.