THE EFFECTS OF MULTIMEDIA INTERFACE DESIGN ON ORIGINAL LEARNING AND RETENTION

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Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE
in
Industrial and Systems Engineering

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December 1996
Blacksburg, Virginia

Keywords: user interface design, human-computer interaction, instructional technology

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(ABSTRACT)

The goal of this research was to compare the learning outcomes of three methods of instruction: a text-based instructional system and two multimedia systems. The two multimedia systems used different interface designs. The first multimedia system used a topic-oriented interface which is somewhat standard in multimedia design. The second multimedia system presented a problem solving context and simulated an industrial setting where the user played the role of an industrial engineer. All three methods presented analogous information about Time Study Analysis, a work measurement technique used by industrial engineers.

A between subjects experimental design with two independent measures examined two domains of learning: verbal information and intellectual skills. This design was used for two sessions to examine original learning and retention components of learning. Original learning was measured immediately following the instructional treatment. Retention was measured two weeks after treatment. Thirty subjects of similar backgrounds (undergraduates in Industrial and Systems Engineering) participated in the experiment’s two sessions. Post-tests were used to measure verbal information and intellectual skills domains of learning during each session. A combined score for both domains was calculated. The scores were analyzed using ANOVA (analysis of variance). No significant differences were found between the three instructional methods for the two domains or the combined score during either the original learning session or the retention session of the experiment.

ACKNOWLEDGMENTS

I would like to thank my committee members, Drs. C. Patrick Koelling, Robert C. Williges, and Robert J. Beaton, for their guidance and advice throughout the course of this research. Pat Koelling deserves special thanks for his patience, humor, and attention even during his sabbatical.

I would like to thank the Southeastern University and College Coalition for Engineering Education (SUCCEED) who funded this project and the Industrial Ergonomics Laboratory and the Multimedia Laboratory where most of the work was done.

Thanks to all my friends at Virginia Tech who have helped me through my coursework and thesis research, and provided breaks from all the work. I would especially like to thank Ron Honaker, my classmate/officemate/labmate/roommate and Megan Jones, my good friend.

Special thanks to Bob Hundley for his encouragement and support during the last two years.

Finally, I would like to extend love and thanks to my parents, Joseph and Barbara Ramsey. Though they didn't get the chance to receive a college education, they provided me and my two brothers and three sisters the opportunity.

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INTRODUCTION

The use of computer-based multimedia systems for education and training is rapidly increasing. Much emphasis has been placed on the technological advancements of these systems. Multimedia systems allow information to be presented as text, audio, graphics, video, and animation. This variety of presentation media permits the generation of impressive displays that are dazzling to eye and ear.

Few studies, however, have ventured to examine the ability of multimedia systems to transfer knowledge or skills to the learner (Bland and Liebowitz, 1995). As part of the Southeastern University and College Coalition for Engineering Education (SUCCEED), the Virginia Tech Department of Industrial and Systems Engineering (ISE) has sought to improve engineering education. This study, funded by SUCCEED, examines the effects of multimedia systems on learning; recognizing the importance of evaluating multimedia as a method of instruction.

The goal of this research is to compare the learning outcomes of three different instructional methods: a text-based instructional system (the control condition) and two multimedia instructional systems (treatments 2 and 3). The text-based instructional system consists of hard-copy (paper) handout with text and illustrations. The two interactive multimedia systems use different interface designs to present the instructional material. One multimedia system (standard multimedia) presents the material in a highly-structured manner, which has become a standard interface for multimedia instructional systems where information is grouped under topics. The second multimedia system (multimedia simulation) creates a role-playing situation were the learner is placed in a simulated industrial environment with fictitious people, places, and events. All three systems present the same instructional material.

The instructional material is based on the topic of Time Study Analysis, currently taught as part of a junior-level ISE course; Work Measurement and Methods Engineering. This study expands on the research by Petitt (1994) who also used the time study topic to compare text-based instruction and multimedia systems for the effects on original learning. Two measures of learning, a measure of original learning immediately following instruction and a measure of retention two weeks after instruction, were performed. The results from the measures of original learning and retention were analyzed using ANOVA to determine which, if any, of the three instructional methods produced superior learning outcomes.

BACKGROUND

Definition of Learning

Learning involves a relatively permanent change in behavior of knowledge due to experience (Chance, 1988). Learning occurs when information is understood and remembered by an individual. Information to be learned can be presented in many ways. Traditionally, learning has relied on a textbook and lecture format for the transfer of knowledge. Technological advancements, in particular multimedia systems, have enabled presentation of information in a number of medias including text, audio, video, graphics, and animation. Multimedia also adds the element of user interaction with the information presented. With the introduction of new media and user interaction comes the challenge for using them effectively to transfer knowledge to the learner. It is important to understand how people learn and process information to successfully design and implement multimedia for learning.

Human Information Processing Model

The cognitive aspects of learning are illustrated by the human information processing model. This model describes human learning as an internal process in which memory is a central element (Gagne, 1985). Human memory is comprised of two components: working (or short term) memory and long term memory (Wickens, 1992). Working memory stores new information temporarily, whereas long term memory stores information in a more permanent manner. Information temporarily stored in working memory can be either committed to long term memory or forgotten.

A three-step process describes how human memory handles informational stimuli (Wickens, 1992). The first step, encoding, describes how information is placed into working memory. The second step, storage, is the manner in which information is encoded. This encoding occurs as spatial (images) and verbal (speech) for working memory or as procedural, declarative, and mental models for long-term memory. The third step, retrieval, is the process of successfully getting information from memory. Figure 1 shows a representation of human memory functions.

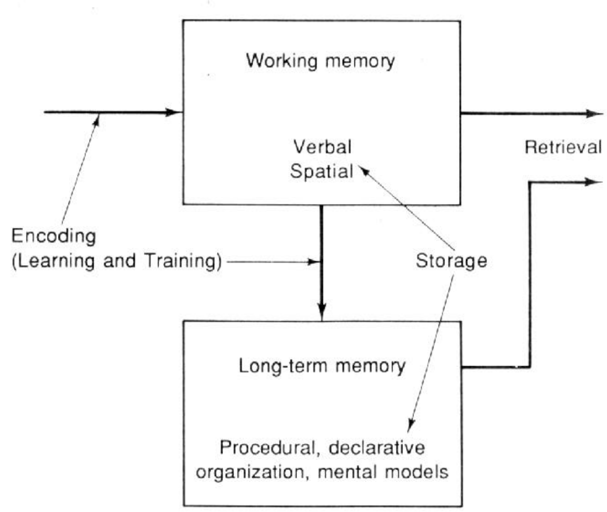

FIGURE 1 Human Memory Model (Wickens, 1992)

Mental Models and Learning

Mental models help learners by providing a framework for understanding the world and how it works. Mental models guide our explanations and interpretations of events and therefore impact what we learn and remember (Norman, 1988). The development of good mental models can provide support that leads to deep understanding and effective retrieval from memory (Hasselbring, 1994). Designers should provide good mental models for people to aid their comprehension of all systems, whether the system is a consumer product or an instructional system.

Levie and Lentz (1982) discuss mental models in providing visual support for comprehension. They studied the use of static pictures (illustrations) accompanying text in children's stories. Their findings suggest that pictures that are decorative (meaning they do not depict actual events from a story) fail to aid comprehension because they do not help children construct mental models of the story situation. On the other hand, pictures that illustrate actual scenes from a story or help organize complex scenes that may be difficult to imagine improve the child's memory of the story.

In contrast, "when source material is entirely in text form, students often have difficulty constructing mental models because they lack knowledge about the concepts or because decoding text takes considerable effort, depriving them of mental resources they could otherwise use to comprehend the information more deeply" (Hasselbring, 1994). Wood (1994) states that up to 30 percent of the population are not able to visualize a concept from a text description. Multimedia systems can help learners construct good mental models by illustrating concepts that are difficult to imagine from a text description alone.

Multiple Resource Theory

Our working memory has limits; we can only process a limited amount of information at one time. How much information can be processed depends on a number of factors including how the information is presented. Multiple resource theory maintains that dividing attention between modalities is better than dividing attention within one modality. Imposing a high load on one modality can cause deficiency of resources and task interference. Separating resources along spatial and verbal modalities leads to better time-sharing and task difficulty insensitivity (Wickens, 1992). Multiple resource theory suggests that many tasks are completed more effectively when different modalities are used together (Blattner, 1994). Multimedia systems can present information in different modalities taking the maximum advantage of the resources available. The National Education Training Group (1995) states that multimedia can improve retention by 25-50% because multiple senses are engaged to reinforce the instructional material.

Dual Coding Theory

Dual Coding Theory (DCT) is an information processing theory that proposes information is coded and processed by separate verbal and non-verbal systems. The verbal system handles text and speech. The nonverbal system handles visual objects, sounds (not speech), visual perceptions, and the feel of objects. Both the verbal and nonverbal systems are part of a symbolic system hierarchy which is orthogonally related to sensorimotor systems. Neale (1994) examined DCT predictions using multimedia systems and found limited support. Dual-coded groups spent less time answering retention questions but performed better than single-coded groups. However, the dual-coded groups spent more time reviewing the material. In addition, a difference between text and speech was found that is not support by DCT.

Components of Learning

The components of learning should be considered when forming goals for an instructional system. Goldstein (1993) lists three components: 1) original learning, 2) transfer, and 3) retention. Original learning refers to the knowledge, skills, and abilities (KSAs) the learner can exhibit at completion of the instruction. Transfer refers to the degree to which the KSAs acquired during instruction will transfer to the actual task environment or can be used to solve some real world problem. Retention refers to the KSAs the learner can exhibit at some time interval after instruction is completed. This study examines both original learning and retention components of learning. Original learning is measured by means of a test administered at the completion of the instruction. This measure allows a comparison of instructional methods immediately following the application of the method as well as a comparison to findings from Petitt (1994). A second test administered two weeks after the first test forms measures retention.

Domains of Learning

Information is very diverse. The nature of information and the domains of learning should be identified in order to properly design an instructional system and to prepare tests measuring learning outcomes. Four domains of learning have been proposed: 1) verbal information, 2) intellectual skills, 3) psychomotor skills, and 4) attitudes (Gagne, 1985; Dick and Carey, 1990). This study concentrates on verbal information and intellectual skills.

Verbal information can be basically described as facts that a person may learn. The learner does not have to apply rules to determine the answer, the learner simply remembers the information so it can be recalled at the appropriate time. This requires a specific answer to a specific question. The learner often must state, list, or describe the verbal information. Examples of verbal information include listing the parts of a machine and reciting the capitals of each state.

Intellectual skills involve problem-solving. The learner must perform some cognitive activity unique to the problem. With intellectual skills, the learner can determine if items are alike or different, can classify things by their characteristics, and can select and apply a variety of rules in order to solve a problem (Dick and Carey, 1990). Examples of intellectuals skills include balancing a checkbook, classifying animals, and determining if two sounds are similar or different.

Changes in the Learning Environment

In order to gain insight into the changing learning environment and how computers are affecting learning, some discussion about trends in instructional design should be considered. Traditionally, learning has relied on a textbook and lecture format for the transfer of knowledge. The student is a passive recipient of knowledge under this format. Traditional schooling treats learning like a savings bank where knowledge is deposited for future use (Papert, 1993). Much of this knowledge remains inert, meaning it is not accessed even though it is relevant for problem solving. When knowledge is acquired through a problem-solving mode, instead of a factual mode, the information learned is less likely to remain inert (Hasselbring, 1994). Students must understand why, when, and how various skills and concepts are relevant or the knowledge will not be used.

Students need the ability to think independently. They should be able to identify and define problems and develop strategies for solving these problems on their own rather than simply responding to problems posed by others. One way to help students become independent thinkers is to anchor instruction in meaningful problem-solving environments (Hasselbring, 1994). Examples of problem-solving environments include scenarios, case studies, hands-on projects, and macrocontexts. Providing students with meaningful problems to solve makes the students a more active participant in the learning environment. Students can see the implications of their new knowledge and learn the appropriate conditions to apply this knowledge (Wilson and Cole, 1991). Providing students with a context-rich, problem-solving environment can therefore increase original learning, retention, and transfer of knowledge to real-world situations.

Computers, especially computer-based multimedia systems, can provide problem-rich environments that help students learn. The simulation multimedia developed as part of this study presents a problem-solving environment for the learner. The student plays the role of an industrial engineer at the (fictitious) ACME faucet company. After a large order for a particular faucet is received, the student is assigned to perform a time study to provide a time standard for assembly of the faucets. It was hoped that by providing a meaningful problem for the students to solve they would better understand why and how time studies are performed and they would retain this knowledge over time.

In contrast, the text-based treatment of this study represents the traditional method of instruction and is considered the control condition. The standard multimedia used in this study provides an interactive forum allowing the student to choose the pace and content sequence for instruction. However, the information is simply presented and this system does not provide a problem-solving context for the student.

<u>Advantages of Multimedia</u>

Potential advantages to multimedia are numerous. Claims ranging from reduced learning time to cost effectiveness abound. Few of these advantages have been evaluated using formal experimentation. In addition, the advantages can be minimized or eliminated by poor design of the multimedia interface. Since the literature discussing advantages of multimedia is so extensive, only advantages with particular impact on the multimedia systems used in this study will be explored.

One major advantage to interactive multimedia systems is the degree of learner control. Learner-controlled instruction allows the student to study material at a pace that suits his/her needs. Students are under less pressure to perform within certain time limits. Learners can choose a logical route through the instructional material that is meaningful to them. Multimedia instructional systems allow learners the opportunity to explore material of their choosing at a pace which is comfortable to them. Students are more interested in the material since they choose the pace and the sequence of the content. This increases the relevance of the material and creates a greater desire to learn, which in turn helps to increase knowledge retention.

Considerable research has shown that students learn more effectively when the instruction is consistent with their cognitive style (Gagne, 1985). Multimedia enables the learner to organize the information in a manner that reflects his learning style, thereby improving the retention and retrieval of knowledge (Norman, Genter, Steven, 1976). The way students review multimedia instructional material mirrors the way they think, learn, and remember. Students move between text and images and sound, stopping for a time to interpret, analysis, and explore. Multimedia adapts well to individual differences due to the high degree of learner control and the ability to map to many learning styles.

Traditional learning relies heavily on reading text that may or may not be accompanied by illustrations. However, the reading comprehension of some students is naturally better than other students. Multimedia can provide dynamic illustrations (animations and video) that offer even more support for comprehension than the use of static pictures studied by Levie and Lentz (1982). In addition, students with varying levels of reading comprehension can use multiple senses to study information. Poor readers are more likely to perform at the same level as more better readers due to the reduced reliance on reading comprehension as the primary means of learning. Multimedia can provide both good and poor readers with more context and support for comprehension than text alone. This helps learners develop better mental models which are key to learning.

<u>Disadvantages of Multimedia</u>

The complexity of a multimedia system and its interface design can increase with an increase in the number of media used. It is important to use media when it is appropriate --when it can better convey information, instead of simply using it to show its technological capabilities. While multimedia systems do exploit technological advances, emphasis should be placed on people using the systems, not the technology. Potential disadvantages to multimedia instructional systems should be taken into account to avoid these pitfalls when designing systems. Conscientious design can help minimize disadvantages.

The non-linear nature of multimedia gives the user freedom to navigate through information in a variety of routes. However, the user can lose their location within the system and become confused about system status. Disorientation means the user does not know where he/she is or how to get somewhere he/she wants. Disorientation becomes more likely to occur and can be more severe as the size of a system and the amount of information it contains grows.

One method of preventing user disorientation is to divide information into sections. Separating information into natural subdivisions makes navigation through the material easier and helps prevent the user from becoming disoriented. The divisions provide reference points, allowing the user to identify where he/she is. Familiar subdivisions such as topic headings and paragraphs exist for text. Identifying divisions is more difficult for other media types. Often the entire media type is considered a chunk of information; for example an entire video clip or audio would be considered a chunk. Each of these chunks should be fairly small in size for easy replay or review of a particular subdivision and good transitions between divisions. Presenting information in small chunks aids learner comprehension and fosters continued interest in the material.

Other methods of preventing disorientation are through the use of scripts and providing the user with information about system status. Some systems use scripts as built-in navigation paths with associated actions and timing. Scripts create the possibility of moving through the system by repetitively clicking at the same location or on the same button. If the user is willing to accept this default, the entire navigation problem is eliminated (Laurel, Oren, and Don, 1990). Information such as words, phrases, or displayed items can be provided to the user to help alleviate the orientation problem (Blattner, 1994).

Another major problem with multimedia systems is related to human information processing limitations. While multimedia can provide engaging displays, bombarding the learner with too much information can lead to cognitive overload. If the learner's attention is divided among too many sources, learning will likely not occur. It is important to maintain the learner's interest but a careful balance must be kept to avert confusion.

To avoid cognitive overload, the number of user choices (links to other areas of the program) should be kept within the 7 ± 2 guideline. Media types should be used to help convey information not simply to impress the user with technology. Proper use of color, font sizes, logical grouping, and location coding can lower the complexity of the system leaving more cognitive resources available for learning. Natural subdivisions of information, navigation aids, and feedback can minimize what the user has to keep track of and remember, thereby reducing their cognitive load.

Both multimedia systems used in this research use the methods discussed to help prevent disorientation and cognitive overload. The instructional information has been divided into four sections. The standard multimedia allows access to any of these sections at any time through the use of global topic buttons that appear at all times. In the simulation multimedia, a guide leads the user to the next section of the program -- creating a default path, or the user can choose a different path or choose to review previously seen information. Other cues are used to provide system status. The standard multimedia shows what section of the program the user is viewing by displaying the topic button as depressed. The simulation multimedia provides an overview of the content and uses a status bar to show the current location.

Multimedia Interface Design

The nature of multimedia permits an enormous variety of interface design possibilities. Good interface design can maximize the advantages of multimedia while minimizing the disadvantages. Interface design issues pertinent to this research include the integration of media, navigation, use of metaphors, standards and guidelines, and the goals of the multimedia system.

A typical problem with early multimedia systems was the tendency to segregate information by the medium of representation. The information should be the focus not the media type used; or in other words, the user is the main consideration not the technology. Good multimedia programs integrate different media types seamlessly. Media integration optimizes the power of all media types by making them accessible to users with equal ease. The interface should provide smooth transitions between media types.

Multimedia frequently uses the metaphor of human-to-human communication as part of the interface design. Guides are interface agents who act as companions to the user. Guides are often used to help with navigation by explaining or suggesting options the user can choose at any particular time. One example of the use of guides for multimedia is the “Americana Series: A CD-ROM Sampler of United States History” developed by Apple in conjunction with Grolier, Inc. (Laurel et al., 1990). Ten guides representing prototypical characters from history were available to help the user navigate and link information together. The role-playing multimedia simulation uses a guide to help explain the actions the user can take to prevent user disorientation.

Few standards exist for multimedia interface design. Since computers have just recently had the computing power to take full advantage of combining media types, some believe that we do not know enough about these systems to standardize. Others believe standards would inhibit innovation (Reed, 1993). However, standards do have benefits. Standards improve the ease of learning and ease of use. Without standards, the user has to re-learn basic navigation for each new screen or program. With standards, a consistent interface allows the user more time to concentrate on the information portrayed and less time figuring out the interface. Standards also facilitate the re-use of user interface design, code, and objects.

The interface design is dependent on the purpose of the multimedia system. The purpose of multimedia systems used in this study is instruction. There is little information on user interface design as it applies to the design and development of educational software (Jones, Farquhar, and Surry, 1995). Park and Hannafin (1993) do provide principles and implications for the design of interactive multimedia for instruction, which are summarized in Table 1.

TABLE 1 Principles and implications for the design of interactive multimedia
(Park and Hannafin, 1993)

Principle	Implication
Related prior knowledge is the single most powerful influence in mediating subsequent learning.	Layer information to accommodate multiple levels of complexity and accommodate differences in related prior knowledge.
New knowledge becomes increasingly meaningful when integrated with existing knowledge.	Embed structural aids to facilitate selection, organization, and integration; embed activities that prompt learner to generate their own unique meaning.
Learning is influenced by the supplied organization of concepts to be learned.	Organize lesson segments into internally consistent idea units.
Knowledge to be learned needs to be organized in ways that reflect differences in learner familiarity with lesson content, the nature of the learning task, and assumptions about the structure of knowledge.	Linkages between and among nodes need to reflect the diverse ways in which the system will be used.
Knowledge is best integrated when unfamiliar concepts can be related to familiar concepts.	Use familiar metaphors in conveying lesson content and designing the system interface.
Learning improves as the number of complementary stimuli used to represent learning content increases.	Present information using multiple, complementary symbols, formats, and perspectives.

TABLE 1 (continued)

Principle	Implication
Knowledge utility improves as processing and understanding deepen.	Provide opportunities to reflect critically on learning and to elaborate knowledge; encourage learners to articulate strategies prior to, during, and subsequent to interacting with the environment.
Learning improves as the amount of invested mental effort increases.	Embed activities that increase the perceived demand characteristics of both the media and learning activities.
Learning improves as competition for similar cognitive resources decreases and declines as competition for the same resources increases.	Structure presentations and interactions to complement cognitive processes and reduce the complexity of the processing task.
Transfer improves when knowledge is situated in authentic contexts.	Anchor knowledge in realistic context and settings.
Knowledge flexibility increases as the number of perspectives on a given topic increases and the conditional nature of the knowledge is understood.	Provide methods that help learners acquire knowledge from multiple perspectives and cross-reference knowledge in multiple ways.
Knowledge of details improves as instructional activities are more explicit, while understanding improves as the activities are more integrative.	Differentiate orienting activities for forthcoming information based upon desired learning; provide organizing activities for information already reviewed.
Feedback increases the likelihood of learning response-relevant lesson content, and decreases the likelihood of learning response -irrelevant lesson content.	Provide opportunities to respond and receive response-differentiated feedback where critical information is involved, but avoid excessive response focusing when incidental learning is expected.
Shifts in attention improve the learning of related concepts.	Differentiate key terms, concepts, and principles through cosmetic amplification, repetition, and recasting.
Learners become confused and disoriented when procedures are complex, insufficient, or inconsistent.	Provide clearly defined procedures for navigating within the system and accessing on-line support.
Visual representations of lesson content and structure improve the learner's awareness of both the conceptual relationships and procedural requirements of a learning system.	Provide concept maps to indicate the interrelationships among concepts, and hypermaps to indicate the location of the learner relative to other lesson segments.
Individuals vary widely in their need for guidance.	Provide tactical, instructional, and procedural assistance.
Learning systems are most efficient when they adapt to relevant individual differences.	Interactive multimedia must adapt dynamically to both learner and content characteristics.
Metacognitive demands are greater for loosely structured learning environments than for highly structured ones.	Provide prompts and self-check activities to aid the learner in monitoring comprehension and adapting individual learning strategies.
Learning is facilitated when system features are functionally self-evident , logically organized, easily accessible, and readily deployed.	Employ screen design and procedural conventions that require minimal cognitive resources, are familiar or can be readily understood, and are consistent with learning requirements.

Systems Approach to Training

Employing a good approach can significantly influence the effectiveness of instructional systems. The instructional systems used in this study were created using a systems approach to help ensure the behavioral objectives are addressed and the goals of the instructional training are met. Hays (1992) states training system development is often fragmented and less than optimally successful because many individuals who influence training development lack a true "systems" approach.

The system approach to training (Dick and Carey, 1990; Gordon, 1994; Williges, 1995) consists of three major phases: 1) specification of training requirements,
2) development of training content, and 3) evaluation of training effectiveness. This user-centered design process places a great deal of emphasis on the user (trainee or student) from the beginning. Figure 2 shows a flowchart of the systems approach to training and interaction between system elements. The systems approach to training is readily applicable to the development of instructional systems for educational use.

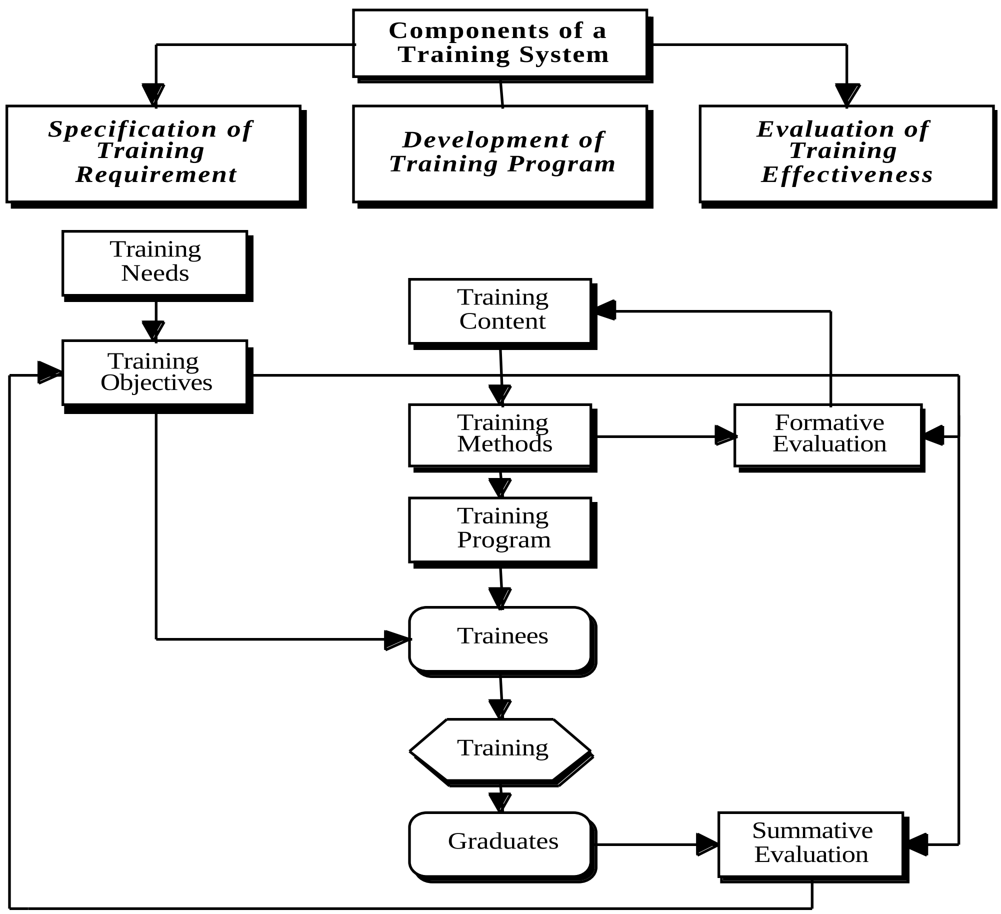

FIGURE 2 The systems approach to training
(adapted from Williges, 1995)

Specification of Training Requirements - The specification of training requirements includes work that should be performed before the instructional program is actually developed. This includes training needs assessment, resource analyses, and creation of functional specifications. The functional specifications include training objectives comprised of goals of the program and behavioral objectives. Each behavioral objective specifically describes the skill or behavior to be learned, the conditions of performance, and acceptable performance criteria. The conditions for performance for each objective will be to perform the objective as part of a written test without the use of reference materials (other than the ones mentioned for the problem-solving section). The subjects are expected to perform each objective to the best of their ability. All three instructional systems used in this study were based on the same set of behavioral objectives, found in Table 2. These behavioral objectives were used as the basis for evaluation of the instruction. Both the test for original learning and the test for retention were based on the behavioral objectives. Dick and Carey (1990) point out that a fair and equitable evaluation system based on behavioral objectives offers two advantages: 1) the student's learning can be monitored, and 2) the effectiveness of the instruction can be examined. The student's learning was measured by the tests taken by the subjects. The second advantage concerning instructional effectiveness is particularly significant for this study since different instructional methods were compared.

Development of training program - The development of the training program includes generating the design concept, initial system development, formative evaluation and user testing, full-scale development and final user testing. Generally, the training/instructional methods are selected by performing a trade-off analysis but for this study the instructional methods of text, standard multimedia, and multimedia simulation

TABLE 2 Behavioral Objectives

Behavioral Objectives (verbal information skills)	
1.	Define a time standard.
2.	Identify two reasons why time studies are performed.
3.	Identify how time standards are useful to a company.
4.	Identify the four basic items of equipment necessary to perform a time study.
5.	Identify the essential quality to look for when selecting an operator to observe for a time study.
6.	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.
7.	Identify the six basic steps involved in collecting the actual time data.
8.	Identify the four basic steps in calculating the time standard from the time data.
9.	Identify how to determine the number of cycles to observe when performing a time study.
Behavioral Objectives (intellectual skills)	
10.	When presented a sample set of time data (on a Form 7), calculate the individual element times and record them in the appropriate cells.
11.	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.
12.	When presented a set of individual element times adjusted for outliers, calculate the average element time for each individual element of the operation.
13.	When presented a set of averaged individual element times adjusted for outliers, calculate the time standard.

were chosen as the basis for comparison. During this phase, the instructional program is iterated to a more optimal design through formative evaluation using representative trainees, those that have the same knowledge, skills, and abilities of the targeted trainee population. Formative evaluation was performed on the text-based instruction and the standard multimedia. Two reviewers, one experienced multimedia developer and one student who had previously taken the Work Methods course, examined these systems. The experimenter explained the purpose of the instructional systems and was present during the evaluation to answer the evaluators questions and record comments. The text-based instruction was judged to be well-organized and clear, thus no changes were made. Some changes were made to the standard multimedia. The formula for calculating the elapsed element time was changed because the element name was slightly different and could have caused confusion. Items that appear on the screen were flashed at a slower rate to attract the user's attention. Other items changed were internal to the system, meaning the changes did not effect what the user would see. These internal changes were made to improve the maintainability of the program. Limited formative evaluation was possible for the multimedia simulation instructional system due to constraints.

Evaluation of Training Effectiveness - The evaluation of training effectiveness is performed through formative evaluation and summative evaluation. The results of the formative evaluation described previously were used to iterate the design of the multimedia simulation. The summative evaluation performed for this study involves the comparison of the three instructional methods for effects on learning, specifically examining original learning and retention. Summative evaluation follows a more rigid experimental design than formative evaluation. The experimental design used for this study is discussed in the Experimental Method section.

Comparisons of Multimedia to other Instructional Methods

Formal studies comprise a small percentage of the abundance of information published about multimedia. Several studies pertaining to the use of multimedia for education or instruction have been performed, including Carrol and Mack, 1984; Egan, Remde, Landauer, Lochbaum, and Gomez, 1989; Marchionini, 1990; Nichol, 1990; Shneiderman, 1987. Many of these studies examine qualitative measures, some look at quantitative measures such as search time or navigation errors. However, few studies have fully examined the ability of multimedia systems to transfer knowledge or skills to the learner (Bland and Liebowitz, 1995). There have been a small number of studies comparing multimedia and hypermedia to conventional instructional methods for learning effects. Two studies that compare multimedia with other instructional methods for effects on learning are Petitt (1994) and Au (1995).

Petitt (1994) compared text-based instruction to standard multimedia and a multimedia system that simulated a mock industrial setting. Original learning was measured by means of a post-test immediately following the review of the instructional material. The scores were recorded and an analysis of variance (ANOVA) performed. Petitt (1994) found a significant effect for the method of instruction. A Newman-Kuels post-hoc test determined the standard multimedia instruction showed significantly better original learning than the text-based instruction. No significant difference was found between the multimedia simulation and text-based as seen in figure 3.

The text-based and standard multimedia system used in this study are essentially the same as those used by Petitt (1994). However, the multimedia simulation program has been substantially changed to address problems identified, to provide a problem-solving context, and to improve the interface design. The simulation multimedia used by Petitt (1994) employed an elevator metaphor where different floors in the mock industrial company corresponded to different topics of the instructional material. For example, the third floor corresponded to the Stockroom where the learner would find out about equipment to be used during a time study. Though the user was prompted what "location" (floor) to go to and what information they would learn at that "location", no natural mapping seemed to exist between the floor name and information presented at that floor. This made it difficult for the learner to review a specific topic since they could not remember how to access the information.

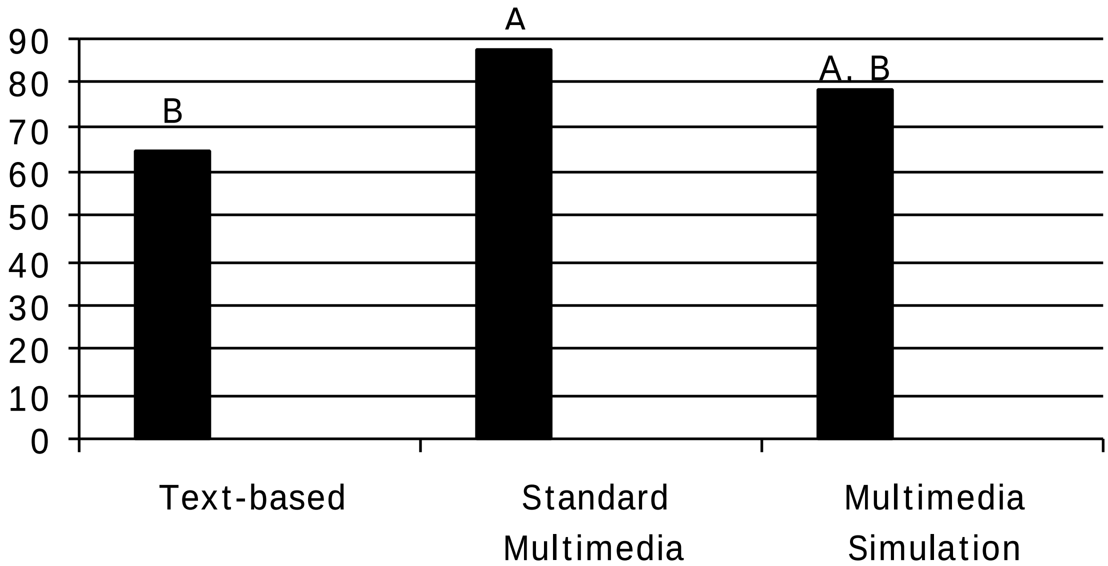

FIGURE 3 Findings from Petitt (1994)

Other problems were identified by Petitt (1994) following the study. Subjects felt compelled to pay attention to the storyline the simulation presented and devoted less cognitive attention to the true instructional material concerning time study analysis. Petitt states the simulation could be improved by providing learners with a problem that is challenging. The simulation multimedia used in this study provides a problem the learner must address. The learner attends a meeting in which a discussion about a large order for faucets presents the learner with the task of performing a time study so the customer can be given an estimate. This context is provided to help motivate the learner and realize the real-world implications for the instructional material. In contrast, while the simulation used by Petitt did provide a fictitious setting it did not provide a problem-solving context for the learner.

This study expands upon Petitt (1994) by providing a measure of retention in addition to a measure of original learning. The simulation multimedia instructional method is a new development effort that has not been examined for effects on learning. The results of the test for original learning from this study are compared to Petitt (1994) to determine if the simulation multimedia performed better.

A study by Au (1995) compared interactive multimedia, an electronic book, and plain text versions of a lesson on management support systems for effects on learning. The main content and theme of the information were identical for all three transmission methods. The subjects were undergraduate business students who were attending an introductory course in information systems. Without prior notice, the students were told at the beginning of class they would take a 15 minute closed-book exam after reviewing material presented in one of the methods. In order to increase the students incentive, bonus points were awarded depending on the score on the exam. The multimedia group consisted of 33 subjects, the electronic book had 55, and the text version 138. (The number of subjects in the computer-supported groups depended on the number of computers available.) The subjects were given a maximum of one hour to study the material before taking the multiple choice exam with 30 questions. Ten questions on the exam were theoretical and presented as text in all three mediums (type I), ten questions on areas that had audio-visual representation in the multimedia systems but were presented by text in the other two systems (type II), and ten questions were to test if subjects were able to apply concept knowledge to other situations (type III). The dependent variable was the score of the exam, counting each type of question separately.

The experiment Au (1995) used a 3x3x2 factorial design with the independent variables of transmission method (multimedia, electronic book, and text), type of questions (types I, II, and III), and subject's score on the midterm exam that had been taken previously (high and low, with high being over 69). To avoid problems with unequal sample sizes, thirty students were chosen from each of the method groups: 15 from the high midterm score subclass and 15 from the low midterm score subclass. Both the high and low midterm groups scored higher with the electronic book than with other methods. The interactive multimedia system had significantly higher scores than text only for the low midterm score group. The high midterm score group performed significantly better than the low midterm score group across all transmission methods. However, the difference between the high and low midterm score groups was twice as large for text-based (14.29%) than for electronic book (6.66%) and interactive multimedia (5.63%). Au suggests that using new mediums for knowledge delivery can potentially reduce the gaps between the performance of students.

The subjects took a second exam a week later to test retention of knowledge. Subjects answered a similar exam with 10 of the 30 questions replaced. Results from the second exam indicated that average scores were higher for electronic book and multimedia groups than for the text group. This suggests the subjects had better retention when the information was presented using computer-based methods.

Simulation as an instructional method

Two reviews of literature on the use of simulation and games for educational purposes and comparisons to more conventional instruction have been performed (Randel, Morris, Wetzel, and Whitehill, 1992; Dempsey, Lucassen, Gilley, and Rasmussen, 1993). Some of the simulations and games were computer-based and others were not.

Randel et al. (1992) reviewed 67 studies published over a 28 year period. Thirty-eight studies showed no difference between games and conventional instruction, 22 favored games, 5 others favored games but their controls were considered questionable, and 3 favored conventional methods. Many of these studies looked for differences immediately following instruction. This would be considered a measure of original learning.

Randel et al. (1992) also examined studies for their findings on retention over time. Fourteen studies measured retention by a delayed posttest performed 10 days to 8 weeks after instruction. Ten (of the fourteen) studies showed a significant increase in retention for simulation/games instruction compared to conventional instruction, whereas four found no difference in retention. Of the ten studies showing significant increase in retention for simulation, seven found no difference between groups at the immediate posttest. The indication that simulation and games are better for retention over time is attributed to the students active participation and the greater chance of information being integrated into the cognitive structure through active participation. Interest was an additional factor examined by Randel et al. (1992). Students reported more interest in simulation and game activities than in more conventional instruction methods in 12 of 14 studies. Randel et al. (1992) suggested that the more interesting instruction is to students, the more motivated the students are to learn.

The review of games in education and training performed by Dempsey et al. (1993) found evidence that games may improve retention of what is learned. Twenty-two research reports comparing simulation or games to conventional instruction were reviewed (some of which overlap with studies reviewed by Randel et al, 1992). For measures for immediate differences, three studies showed significant immediate differences in favor of simulation and games while the same number (three) favored conventional methods. The majority (15) of the studies found no immediate differences. However, eleven of the 22 studies assessed retention through a later posttest. In eight (of eleven) studies, retention was found significantly better with simulation and gaming, while three found no difference.

Summary

This study examines both original learning and retention components of learning. Original learning is measured by means of a test administered at the completion of the instruction. This measure allows a comparison of instructional methods immediately following the application of the method. However, since several research studies (Au, 1995; Dempsey et al., 1993; Petitt, 1994; Randel et al., 1992) have shown no differences between multimedia and text-based instructional methods when measured immediately after completion of the instruction, more information was needed to determine the effects of instructional methods on other components of learning. This study therefore examines the effect of instructional method on retention as well as original learning. As pointed out, several studies (Au, 1995; Dempsey et al., 1993; Randel et al., 1992) showed no differences when measuring for original learning, but in some cases showed higher retention of material presented through the use of simulation. This study compares text, standard multimedia, and multimedia simulation for original learning and retention of material presented. It is possible that the more the multimedia involves the learner as an active participant the more the learner may retain of the information presented.

EXPERIMENTAL METHOD

As previously explained, this study compares text-based instruction with two computer-based multimedia systems; one standard and one simulation. The basis for comparison is the degree of original learning and retention. Original learning refers to the knowledge, skills, and abilities (KSAs) the learner can exhibit at completion of the instruction. Retention refers to the KSAs the learner can exhibit at some time interval after instruction is completed.

Instructional Content

The instructional content covers Time Study Analysis, a work measurement technique used by industrial engineers. The topic is ordinarily covered in junior level (third year) college courses. The content of the instruction for this research, although not comprehensive, includes the definition of a time study, reasons a time study is performed, basic equipment needed to perform a time study, and data collection and analysis procedures.

The content of all three instructional methods is analogous. By minimizing differences in the content, there is a greater chance of finding the method of instruction that is more effective in terms of degree of original learning and retention. The instructional content and wording in each method are as similar as possible, only the presentation method is changed. The text handout and standard multimedia consist only of instructional material. In the simulation multimedia, the instructional material is preceded by a virtual meeting that creates a problem-solving context for the learner.

Subjects

The subjects used for this experiment were 30 college undergraduate students enrolled in Industrial and Systems Engineering (ISE) at Virginia Tech. Most subjects were from the sophomore (second year) level, given the Work Methods course is generally offered during the junior (third) year. Only students who had not previously taken Work Measurement and Methods Engineering were considered since time study analysis is covered during that course. This choice of subjects minimized individual differences with respect to prior knowledge. A screening questionnaire (see Appendix A) was used during the selection of subjects to ensure the subject is enrolled in ISE and had not previously taken Work Methods or been exposed to concepts of time study analysis. Ten subjects were randomly assigned to each treatment condition. Subjects were paid $7.00 per hour for their participation in the experiment.

Experimental Design

The experimental design used a one factor between subjects design with two dependent measures. The between subjects variable, Method of Instruction, consisted of three levels: text, standard multimedia, and multimedia simulation. The dependent measures assessed two domains of learning: verbal information and intellectual skills. These domains of learning were measured through separate sections of the tests administered to the subjects. One test was taken by the subjects immediately following the administration of the treatment to measure original learning. A second test was administered two weeks later to measure retention. The effectiveness of each Method of Instruction was compared for the two domains of learning using an analysis of variance (ANOVA). A combined score of both measures was compared across the Method of Instruction.

Treatment Conditions

Three treatment conditions are used in this study: 1) text-based instruction, 2) standard multimedia, and 3) simulation multimedia. Treatment Condition 1, the text-based instruction, is organized by main topics followed by detailed information. The four main topics are: 1) an introduction to time study analysis, 2) time study equipment, 3) collecting time data, and 4) analyzing time data. Illustrations and tables are included to help the learner visualize and organize information. Appendix B contains the text-based instructional material. The content for the standard multimedia, Treatment Condition 2, is also organized by the four main topics listed above. A button for each topic is present at all times so the learner can access that section of the program. After a topic button is chosen, the instructional information for the chosen section is presented in a large window. More information about the section can then be accessed through the use of a Next button, or the information can be reviewed by pressing the Replay button or the Back button. A more detailed description of the standard multimedia treatment appears in Appendix C. Both the text-based instruction and the standard multimedia system are the same or very similar to the ones used in the Petitt (1994) study, with only errors or bugs removed or fixed. The simulation multimedia, however, was substantially changed to incorporate a new interface and to avoid problems pointed out by Petitt (1994).

The simulation multimedia, Treatment Condition 3, represents a more active learning environment than the standard multimedia or text-based instruction. The simulation involves the learner by depicting a day on the job at a faucet manufacturing company. The learner attends a meeting with other "people" to discuss the need to perform a time study analysis. The learner then accesses information from "books" that cover the same topics as the text handout and standard multimedia. Appendix D contains a more detailed description of the simulation multimedia system. Again, the instructional content of all three systems is analogous. The simulation multimedia provides more context and involves the learner as an active participant.

<u>Experimental Procedures</u>

Informed Consent and Instructions - Upon arriving to the experiment, subjects completed the informed consent form, found in Appendix E, and were given a written explanation of the experiment and its purpose, found in Appendix F. Subjects then completed the screening questionnaire to confirm they have not taken Work Methods and were not familiar with time study analysis. After screening, subjects without prior knowledge of time studies were verbally reminded that they would be tested at the end of the session and again two weeks following the first session. The subjects' goal was to maximize their scores on the post-tests by careful review of the instructional content.

Assignment of Subjects to Treatment Groups - Subjects were assigned to treatment groups randomly. Each of the thirty subjects were assigned a number from 1 to 30 through the use of a random number generator. Subjects 1 through 10 were assigned to the Treatment Condition 1 (text), subjects 11 through 20 were assigned to Treatment Condition 2 (standard multimedia), and subjects 21 through 30 were assigned to Treatment Condition 3 (multimedia simulation). Table 3 represents the experimental design with subject assignment to treatment conditions.

TABLE 3 Experimental Design with subject assignments

Domain of Learning	Instructional Treatment Condition: Text		Standard Multimedia		Simulation Multimedia	
Verbal Information	S01 S02 S03 S04 S05	S06 S07 S08 S09 S10	S11 S12 S13 S14 S15	S16 S17 S18 S19 S20	S21 S22 S23 S24 S25	S26 S27 S28 S29 S30
Intellectual Skills	S01 S02 S03 S04 S05	S06 S07 S08 S09 S10	S11 S12 S13 S14 S15	S16 S17 S18 S19 S20	S21 S22 S23 S24 S25	S26 S27 S28 S29 S30

The subjects received the treatment they had been randomly assigned. The text-based treatment group was provided a bare table to review the material. The multimedia treatment groups were provided a Macintosh computer with a mouse to review the material. The experimenter was available to answer questions about the treatment but did not provide assistance concerning the material content. The subjects were told to review the instructional material to the degree they feel ready for the test. Subjects then asked the experimenter for the test to complete. Subjects were provided a calculator, pencils, and tables containing information to assist in problem solving. Upon completing the test for original learning, subjects scheduled a time for the test for retention two weeks later. Following the second session, subjects were paid for their time and thanked for their participation.

Tests for Measurement of Original Learning and Retention

Two tests, form A and form B, were used to measure learning outcomes. Form A is provided in Appendix G and form B in Appendix H. Each test consists of two sections: section 1 tests the subjects' verbal information abilities and section 2 tests subjects' intellectual skills. The verbal information section contains short answer, multiple choice, and/or ordering questions. The intellectual skills section contains problems to be solved. In form A, questions 1 through 9 cover verbal information and questions 10 through 12 cover intellectual skills. In form B, questions 1 through 8 cover verbal information and questions 9 through 11 cover intellectual skills.

All test questions were based on the behavioral objectives to help ensure a fair and equitable evaluation system (Dick and Carey, 1990). The test forms both cover the same information but ask questions in a different format to help prevent a practice effect where the subjects memorize answers to the first test as a way to improve scores on the second test. For example, form A contains a multiple choice question about the ordering of the steps to analyzing time study data while in form B subjects must number the steps. In addition, all numbers used in the problems are different in form A than form B.

The degree of original learning was measured using a post-instructional test administered immediately after the instructional treatment. Retention was measured two weeks after the test for original learning.

The two test forms were counterbalanced for each treatment group. Of the ten subjects in each group, five received form A and five received form B as the measure for original learning.

The corresponding form was then be used as the measure of retention so each subject would take both forms of the test.

Grading Guidelines for Post-Tests

An answer key for each test was developed prior to the administration of the tests. The answer keys provide guidelines for assigning points to correct answers for each test question. The answer key for form A is provided in Appendix I. The answer key for form B is provided in Appendix J.

Results from Pretesting

Four subjects were used in a pilot test using the text-based instruction and the standard multimedia treatment conditions. The simulation multimedia was undergoing evaluation and was not used in pretesting. Results from the pretests show the verbal information scores were significantly higher for the standard multimedia than for text-based instruction. No differences were found in the problem solving or combined scores for the two treatments considered. Since a small number of subjects was used for pretesting, these results may be different from the actual experiment.

No changes were made to the instructions or the instructional systems since the pilot subjects did not suggest any changes were necessary. Pretesting provided the experimenter with an opportunity to carry out the experimental protocol.

RESULTS

Using the experimental method explained, data were collected from 30 subjects. Each subject participated in two sessions. The first session presented the treatment and measured original learning for two domains of learning: verbal information and intellectual skills (problem-solving). The measures were gathered by means of a test given to the subject after treatment. The second session was held two weeks after the first session for each subject. The second session measured retention for the same domains of learning by means of a second test. Different test forms with changes in wording, problem-type, and numbers used in calculations were used for each measure to help prevent a practice effect where subjects could memorize the answer from the first test to use on the second test.

Raw Scores for Original Learning and Retention

The tests were graded using the answer key guidelines developed prior to the administration of the tests. Each domain of learning section was graded separately. An overall average score for each test was also calculated. Table 4 shows the complete set of raw scores arranged by treatment group. Each row of the data table represents a subject's scores for the two sessions.

TABLE 4 Raw Scores for Original Learning and Retention

	Original Learning			Retention		
Treatment	Verbal	Problems	Overall	Verbal	Problems	Overall
Text	94	75	84.5	91	97	94
	89	94	91.5	49	87	68
	87	55	71	74	85	79.5
	71	97	84	73	97	85
	85	100	92.5	93	100	96.5
	99	100	99.5	80	100	90
	99	100	99.5	99	100	99.5
	75	80	77.5	84	90	87
	88	90	89	70	85	77.5
	91	95	93	74	91	82.5
Standard MM	87	100	93.5	94	92	93
	93	91	92	91	100	95.5
	94	100	97	90	100	95
	97	97	97	78	100	89
	96	100	98	84	100	92
	96	97	96.5	77	97	87
	73	100	86.5	75	100	87.5
	85	87	86	77	97	87
	83	97	90	82	100	91
	74	100	87	72	82	77
MM Simulation	78	100	89	71	100	85.5
	96	97	96.5	91	100	95.5
	94	90	92	88	100	94
	87	100	93.5	80	100	90
	93	100	96.5	85	95	90
	84	100	92	70	100	85
	69	77	73	61	70	65.5
	58	97	77.5	69	94	81.5
	72	77	74.5	71	85	78
	74	97	85.5	76	75	75.5

Means and Standard Deviations for Original Learning and Retention

Means and standard deviations were calculated for the verbal information and problem-solving (intellectual skills) sections as well as the overall test score. Table 5 shows the means for the original learning and retention sessions of the experiment. Table 6 shows the standard deviation by treatment method.

TABLE 5 Means for Scores

	Original Learning			Retention		
Treatment	Verbal	Problems	Overall	Verbal	Problems	Overall
Text	87.8	88.6	88.2	78.7	93.2	85.95
Standard MM	87.8	96.9	92.35	82	96.8	89.4
MM Simulation	80.5	93.5	87	76.2	91.9	84.05

TABLE 6 Standard Deviations for Scores

	Original Learning			Retention		
Treatment	Verbal	Problems	Overall	Verbal	Problems	Overall
Text	9.163	14.607	9.129	14.268	6.286	9.576
Standard MM	8.979	4.483	4.744	7.513	5.808	5.374
MM Simulation	12.439	9.204	8.954	9.578	11.328	9.215

Some interesting observations can be made from the mean and standard deviation information. Overall, the scores were high for both the original learning and retention phases of the experiment. The text-based treatment mean score for retention (score = 93.2) was higher than the score for original learning (score = 88.6). The subjects receiving the text-based instruction performed better on the problem-solving section at the retention phase of the experiment, two weeks after reviewing the instruction, than at the original learning phase, immediately following the instruction. For the other treatments, the mean scores were lower for retention than for original learning. The standard deviation for the standard multimedia treatment was always lower than the other treatment methods. This suggests the scores were more homogeneous for the standard multimedia instructional method.

Analysis of Variance for Original Learning

The data for original learning were analyzed using analysis of variance (ANOVA) for each domain of learning and for the overall score using an alpha level of 0.05. Each domain of learning was examined to determine if a significant difference in instructional method resulted. The overall score was analyzed to see if a significant difference resulted when examining the test score including both domains of learning.

Table 7 shows the ANOVA table of the verbal information section for original learning. No significant differences between treatments were found for this section.

TABLE 7 ANOVA of verbal information for original learning

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Instructional Method	2	355.267	177.633	1.669	.2073
Residual	27	2873.700	106.433		

Dependent: OL - Verbal

Table 8 shows the ANOVA table of the problem solving section for original learning. No significant differences between treatments were found for this section.

TABLE 8 ANOVA of problem solving section for original learning

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Instructional Method	2	348.200	174.100	1.641	.2124
Residual	27	2863.800	106.067		

Dependent: OL - Prob Solv

The overall score is an average of the scores from the verbal information and problem-solving sections of the test. No significant differences were found for the overall score for original learning as seen in Table 9.

TABLE 9 ANOVA of overall score for original learning

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Instructional Method	2	157.617	78.808	1.271	.2968
Residual	27	1674.125	62.005		

Dependent: OL - Total

<u>Analysis of Variance for Retention</u>

The data for retention, like the data for original learning, were analyzed using analysis of variance (ANOVA) for each domain of learning and for the overall score using an alpha level of 0.05. Each domain of learning was examined to determine if a significant difference in instructional method resulted. The overall score was analyzed to see if a significant difference resulted when examining the test score as a whole.

Table 10 shows the ANOVA table of the problem solving section for retention. No significant differences between treatments were found for this section.

TABLE 10 ANOVA of verbal information section for retention

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Instructional Method	2	169.267	84.633	.722	.4950
Residual	27	3165.700	117.248		

Dependent: Retention - Verbal

Table 11 shows the ANOVA table of the intellectual skills section for retention. No significant differences between treatments were found for this section.

TABLE 11 ANOVA of problem solving section for retention

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Instructional Method	2	128.867	64.433	.959	.3960
Residual	27	1814.100	67.189		

Dependent: Retention - Prob Solv

The overall score is an average of the scores from the verbal information and problem-solving sections of the test. No significant differences were found for the overall score for retention as seen in Table 12.

TABLE 12 ANOVA of overall score for retention

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Instructional Method	2	147.117	73.558	1.074	.3558
Residual	27	1849.350	68.494		

Dependent: Retention - Total

No post-hoc tests were performed since the treatment main effect was not significant for verbal information, problem solving, or combined scores in either of the original learning or retention phases of the experiment. In addition, the p-value for each ANOVA table shows that the treatment effect would not be significant if the alpha level was changed to 0.20.

Since no significant differences were found for the two major sections of the tests, finer level analyses were performed to examine specific topics and questions. An analysis was performed to determine if any of the treatment groups performed better on questions from a particular topic covered in the instructional material. No differences between the treatment groups were found when examining the scores on questions from the four topics covered.

A question-by-question comparison for the three instructional methods did show differences for an alpha level of 0.20. During the original learning session, three questions showed differences: the labelling of the sections of the Form 7 ($p = 0.1649$) from the verbal information section, and the calculation of an adjusted data set ($p = 0.1818$) and the calculation of the time standard ($p = 0.0666$) from the intellectual skills section. The text group (mean = 9.6) performed worse than the standard multimedia group (mean = 11.4) and multimedia simulation group (mean = 11.4) on the labelling the Form 7 question which was worth 12 points. The standard multimedia group (mean = 25) performed better than the text group (mean = 21) and the multimedia simulation group (mean = 20) on the calculation of the adjusted data set question which was worth 25 points. The text group (mean = 19) performed worse than the standard multimedia group (mean = 24) and the multimedia simulation group (mean = 25) on the calculation of the time standard question which was worth 25 points.

For the retention session, one question about the reasons for performing a time study showed difference ($p = 0.0806$). The multimedia simulation group (mean = 6.2) performed worse than the text group (mean = 8.4) and the standard multimedia group (mean = 9.3) for the time study rationale question which was worth 12 points.

DISCUSSION

This research intended to discover if differences exist between three instructional methods: text-based system (control) and two multimedia systems. It was hoped the data would show if multimedia instructional systems resulted in superior learning. And, if the multimedia systems were found to be superior, to determine how to design the multimedia interfaces to best convey information to the learner.

Two different multimedia interfaces were compared: a topic-oriented system and a role-playing simulation. Topic-oriented interfaces are fairly standard for multimedia, particularly kiosks. The simulation multimedia aimed to provide a more active learning environment by presenting the learner with a problem-solving context that would hopefully help them realize the relevance of the instructional material and retain it better.

The study examined original learning immediately following instruction and retention of instructional material two weeks after instruction. A review of the literature indicated that previous studies examining simulation and more traditional instructional methods such as text most often showed no significant differences for measures taken immediately following instruction (original learning). In Randel et al. (1992), 38 of 67 studies showed no differences and 15 of 22 studies reviewed by Dempsey et al.(1993) showed no differences for original learning. Some studies did show significant differences between simulation and other instructional methods for retention. Ten of 14 studies in Randel et al. (1992) and 8 of 11 studies reviewed by Dempsey et al.(1993) showed higher learning effects for simulation-based instruction.

The results of the original learning phase of the experiment showed no significant differences between the instructional methods. This is consistent with the findings in the review of the literature. However, it is not consistent with the findings of Petitt (1994), who found the standard multimedia system resulted in significantly higher scores than the text-based method. Since the subjects were taken from the same population (undergraduates in ISE) and the text-based instruction and standard multimedia system used in this study were substantially the same as the one used by Petitt, this finding was not expected. It could be said that the novelty of multimedia caused Petitt's subjects to pay closer attention to the instruction which resulted in higher scores. Subjects in this study may be more familiar with multimedia systems than those in Petitt's study and therefore no novelty effect existed. However, the simulation multimedia system used by Petitt was not found significantly different than the text-based treatment.

The results of the retention phase of the experiment showed no significant differences between the instructional methods. This is not consistent with the findings in the review of literature.

Multimedia and simulations may be more effective in certain contexts than others. As pointed out in the publications reviewed in this study, up to 30 percent of people cannot visualize a concept from a text description (Wood, 1994). Multimedia can help illustrate ideas through the use of media other than text; such as video and animation. In the multimedia systems used in this study, video was used to demonstrate an engineer performing a time study and a worker assembling a part, and animation was used to show how pieces form a part. But, the topic of time study analysis is a fairly straightforward topic with few difficult-to-imagine concepts.

Topics where concepts are more difficult to imagine than the topic used in this experiment might benefit more from multimedia presentation of information. Video and animation can dynamically illustrate concepts, and audio can provide emphasis to help convey ideas. In particular, concepts that cannot be naturally observed are likely to be difficult to imagine. An example of a difficult to imagine concept that cannot be observed naturally (by the human eye) is the atom. A text description of how electrons circle the nucleus may be hard to visualize. A simple animation of an atom could show a learner more than a text description with static illustration.

Contexts that require high use of one modality can be divided into different modalities to help resource sharing. In a context where the visual modality may be overloaded, using the auditory modality in addition to the visual can aid user comprehension.

The multimedia systems used in this study attempt to maximize the benefits of multimedia while minimizing the disadvantages. From direct observation of the subjects during the experiment and subject feedback, it is believed that subjects did not suffer from disorientation or cognitive overload. Many subjects did express a heightened interest in the multimedia systems as a way of presenting information. Motivation can have a effect on learning outcomes.

The simulation multimedia system used in this study presented a problem-solving context for the learner to anchor the instruction in a meaningful environment. While the simulation multimedia did not perform significantly better than the other methods, it did seem to provide the subjects with a clear idea of how time studies can be used. The subjects in the simulation multimedia treatment group gave detailed answers to the test question that asks how time standards are useful to a company. Other groups did not perform significantly worse on the test question, but did not provide the same level detail compared with the simulation group. It is important to convey how time studies are performed but it is also important to understand why and when they are done.

While the multimedia systems were not shown as superior learning tools in this study, they were also not shown as inferior ones in terms of the transfer knowledge or skills to the learner. However, multimedia systems generally require a substantially greater level of effort to create compared to text-based instruction. When taking into account the level of effort required to build each instructional system, multimedia systems could be seen as more effort without benefit. Careful comparisons need to be made that take into account many factors. If a multimedia system is used for a period of time, the initial cost may be more justified. Multimedia systems can be used independently by students. No instructor time is required. Over the course of several semesters, the multimedia system can actually cost less than lecture instruction.

From the question-by question analyses, three questions showed significant differences between treatment groups during the original learning phase and one question showed significant differences between treatment groups during the retention phase. This may be the result of the discrete nature of the points assigned to answers provided. No differences were found between the treatment groups for the topics covered in the instructional material.

The tests used to measure subject performance consisted of a limited number of questions for each domain of learning. The problem-solving section of the tests were comprised of four questions, each worth 25 points. The credit for each question was based on if the calculations were performed correctly as well as the final numerical answer. All subjects were encouraged to show their work so that if an error was made, partial credit could still be awarded for the proper procedure. Some subjects did not show their work on the problems and thus, no partial credit could be awarded. This helps explain why subjects in the text treatment performed better on the retention phase of the experiment than the original learning phase. A test with more questions and increased difficulty would be a more sensitive measure to show differences between the instructional methods.

Future research

This study looked for differences in instructional methods by measuring subjects performance on tests following instruction. No basis for comparison of subjects was collected prior to the experiment. As in Au (1995), separating the data into groups by some prior intellectual measure may show more information. The data could be analyzed to see if typically low performers show scores closer to high performers for multimedia systems when compared with text. This would suggest the reduced reliance on reading comprehension for multimedia instruction systems helped the low performers improve their scores.

The original learning and retention components of learning were examined in this research. Transfer of training is another component of learning that deserves consideration. Transfer refers to the degree to which the learner can exhibit the knowledge, skills, and abilities learned to a real world situation. It is possible that simulation-based training would lead to a higher degree of transfer of training when compared to other methods since simulation places the learner in a real world situation during learning.

Information about subject preference for a particular method could be collected. Subjects may prefer learning using multimedia systems more than text-based instruction. While preference alone is not necessarily a justification for multimedia instruction, subjective measures may provide more insight for the comparison of multimedia with other instructional methods and the design of multimedia interfaces.

The Internet is become a very popular means of delivering instructional material. To date, the majority of the content delivered over the Internet has been non-interactive hypertext with limited graphics (images). Advances in technology now allow interactive multimedia content to be delivered over the Internet. A study funded by SUCCEED will compare the topic-based multimedia system used in this study with an Internet-based system that delivers analogous content. Shockwave is being used to convert the multimedia system into Internet-deliverable content.

During the experiment, the subjects often reviewed the material more than once. Some of the topics covered consisted of several sections. For example, the topic of collecting time data consists of five sections. Two subjects in the standard multimedia group noted that it would be nice to have a way to skip to the latter sections of a topic. No changes were made during the course of the experiment in order to prevent problems with validity. These comments should be taken into consideration during future research.

Multimedia allows for a infinite variety of interface designs. More research into the optimum display modalities for information needs to be performed in order to use multimedia to its maximum advantage. While the simulation multimedia program did not perform significantly better in this study, more information on the use of simulations as an instructional method would be helpful to instructional designers. Research to determine what, if any, contexts are more adaptable to multimedia and simulation methods needs to be performed.

CONCLUSIONS

Multimedia systems are becoming more prevalent in education and training. The advances in multimedia technology allow information to be presented in unlimited variety of choices, as well as provide interactivity for the user. The introduction of multimedia technology alone is not enough to improve learning; multimedia design is important. The most effective media combinations should be used to convey information.

The goal of this research was to compare a traditional text-based instructional system with a standard topic-oriented multimedia system and a role-playing simulation multimedia system. No significant differences were found between the three instructional methods for verbal information and intellectual skills domains of learning during the original learning or retention phases of the experiment. This makes it clear that simply presenting information in a multimedia format does not necessary improve learning over other more traditional formats.

More research needs to be performed to determine if multimedia is truly a superior learning format. The most effective ways to present multimedia information needs to be explored. Research is still in the early stages for determining the optimum display modalities to aid learning. The contexts in which multimedia can best illustrate concepts and therefore make the largest contribution have yet to be identified. The different components of learning need to be examined. Many studies have focused on original learning, but retention and transfer of training should also be analyzed.

Multimedia is a breakthrough in technology. It is important to ensure multimedia systems work effectively in terms of transferring knowledge to the user. This is especially true if the multimedia systems are to replace existing forms of instruction.

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Appendix A

Subject Screening Questionnaire

Subject Screening Questionnaire

Are you an undergraduate Industrial and Systems Engineering student? (If no, please list major and level)

Have you ever taken a course in or had experience with work methods engineering or other related principles? (If yes, please elaborate)

Have you ever had exposure to or experience with performing time studies? (If yes, please elaborate)

Thank you.

Appendix B

Text-based Instructional Treatment

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

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 need something to record the time data with. A pencil should be used in case you make errors and need to erase.

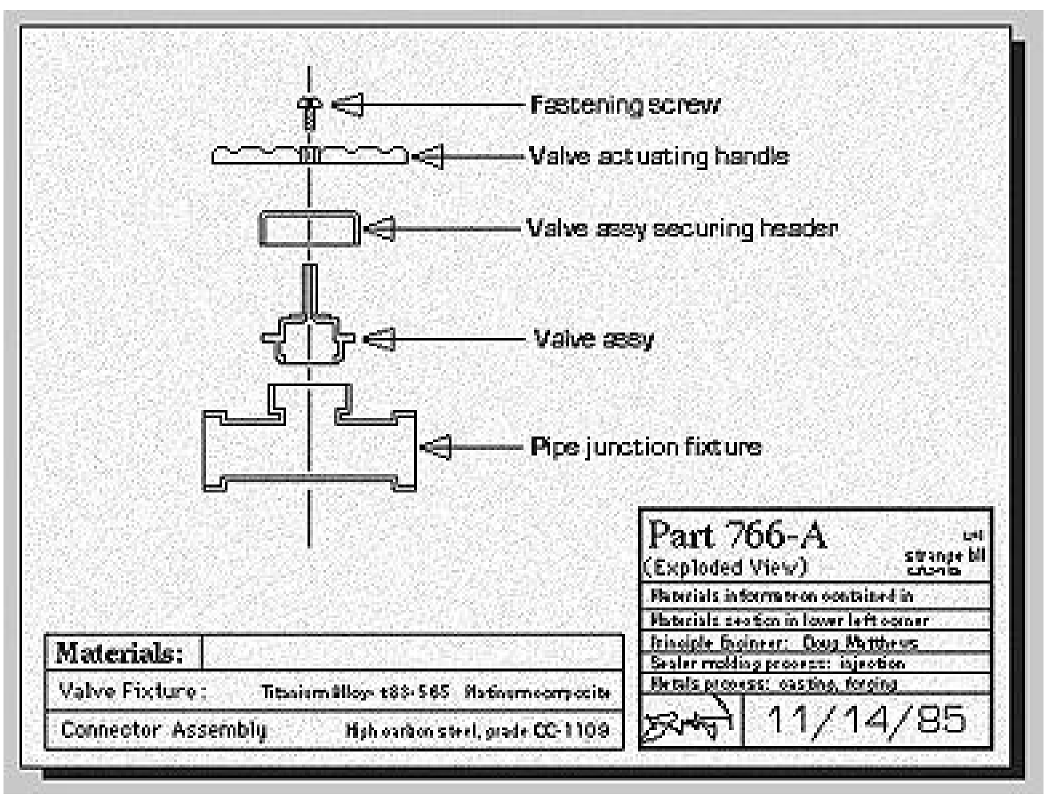
Collecting Time Data

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:

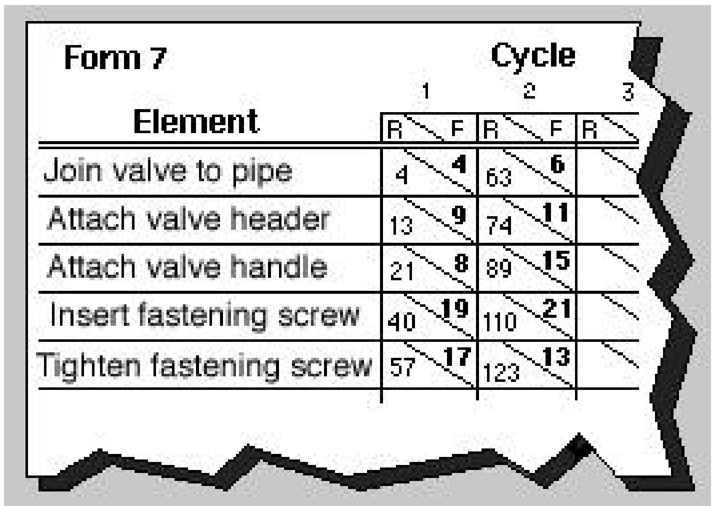
Form 7

Element	Cycle 1 R	1 F	2 R	2 F	3 R	3 F	4 R	4 F	5 R	5 F	6 R	6 F	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 four 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

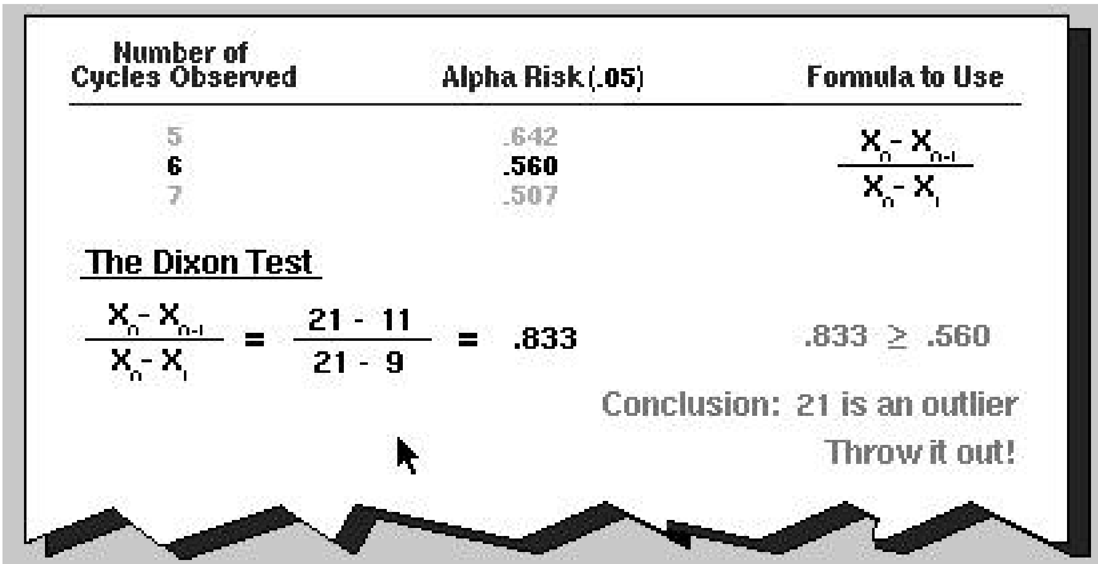
Element Times (ascending order): **9 9 10 11 11 21**

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

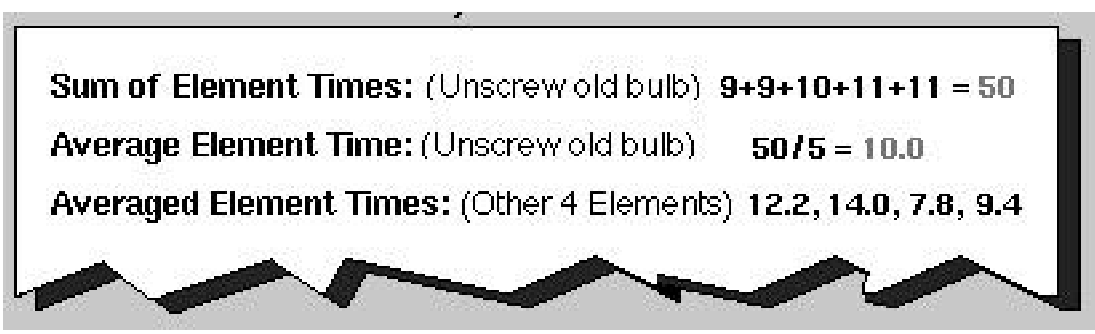
Number of Cycles Observed	Alpha Risk (.05)	Formula to Use
3	.941	
4	.765	
5	.642	$\frac{X_n - X_{n-1}}{X_n - X_1}$
6	**.560**	
7	.507	

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.

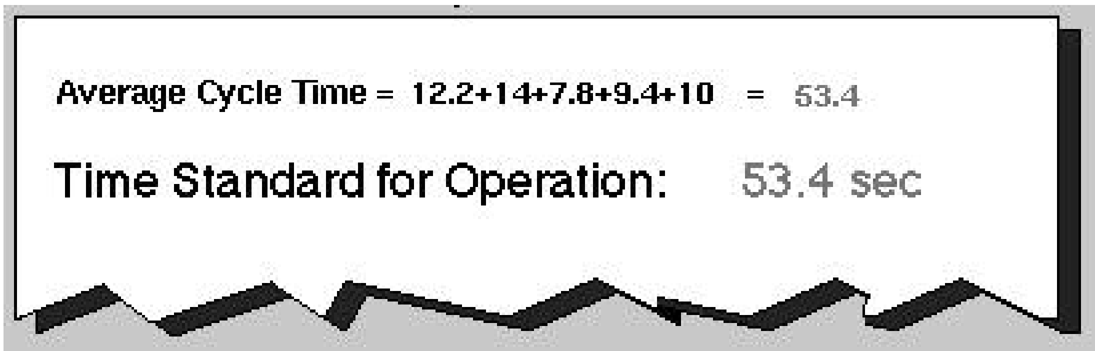


You should continue performing this test on each element time. Remember, you listed the element times in ascending order. So as soon as you discover that a data point is *not* an outlier, you can stop.

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.



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 C

Description of 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 text-based control condition, the program is 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 allow the learner to select any of these topic areas at any time. This affords the learner easy navigation and backtracking.

In each topic area there is more information presented than can be displayed on the screen simultaneously. To accommodate this, learners are provided Next and Back buttons to allow them to flip forward or backward between screens of information. There is also a button located between the Next and Back buttons that gave learners control of replaying the sound and/or video/animation segment presented in each screen.

The narrator's voice is synchronized with information that appears on the screen. Each screen is explained in terms of what is spoken and what information is displayed.

Figure 4 below shows a typical screen of information and the universal interface layout.

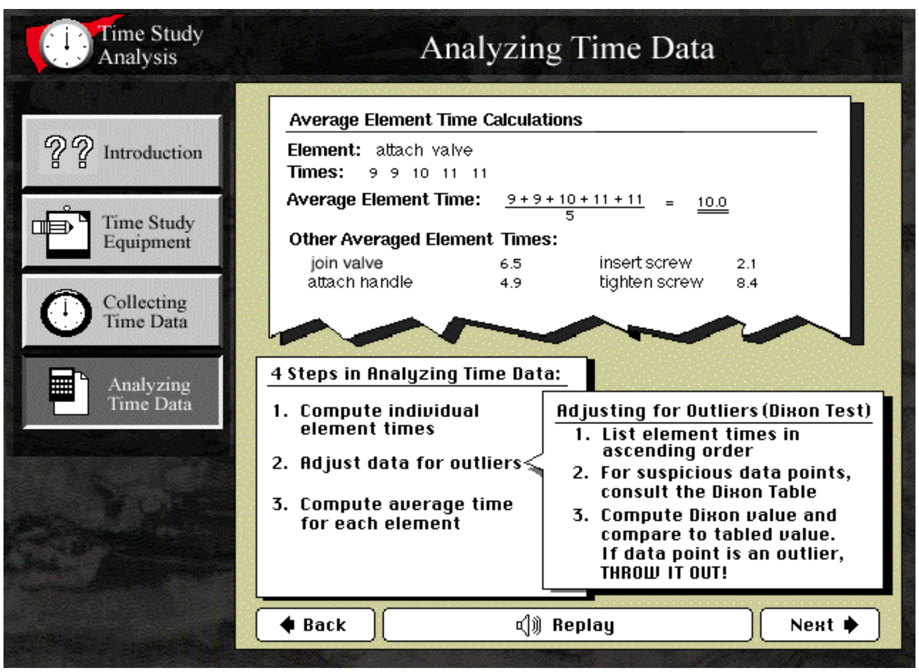


FIGURE 4 Standard Multimedia Interface

The program begins 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 (synchronized 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

[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: "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 need 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 7. 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 of 60 cycles for .5 minutes 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 D

Description of Multimedia Simulation

Instructional Treatment 3: Multimedia Simulation

This is a detailed description of the design and layout of instructional treatment 3 (Multimedia Simulation). The simulation involves the learner by depicting a day on the job at a industrial manufacturing company, the ACME faucet company. The learner attends a meeting with other "people" to discuss the need to perform a time study analysis for a particular faucet assembly. The learner then accesses information from "books" to learn more about time studies, the equipment needed, and how to collect and analyze time data. The simulation multimedia uses a guide to help the learner with navigation and provide information to the learner.

At the beginning of the program, the guide explains the user's role in the program, the sections of the program, and the use of buttons appearing on the screen. For example, the Menu button allows the user to switch between the two major sections of the program: the meeting and the bookshelf.

Guide: These are the other people attending the meeting. You can get a brief introduction to any of these folks if you like, and whenever you're ready you can start the meeting.
(pictures of the people of the meeting appear. The other people are:
Al: vice-president of manufacturing
Russ: head of production control
Diane: senior sales manager
Fred: assembly supervisor
Roy: assembler)

Figure 5 shows the other people at meeting:

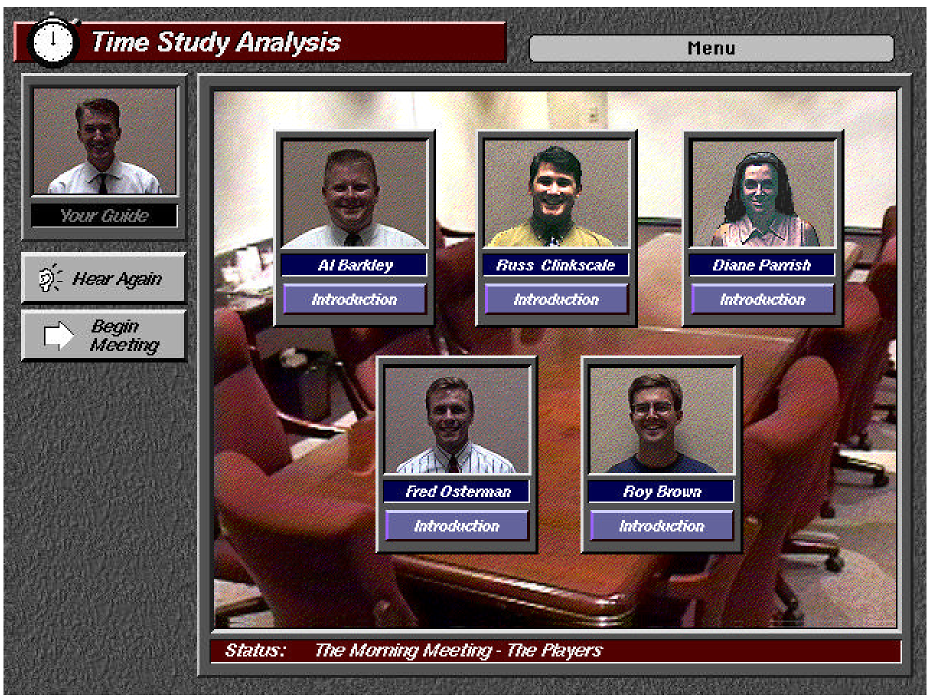


FIGURE 5 Virtual meeting interface for simulation multimedia

Guide: "During the meeting, one person will speak at a time. After a person has finished speaking, you can hear them repeat what was said or you can keep the meeting rolling along."

(Each person's picture lights up when they are speaking.)

Al: "Good morning everyone. Hope you all had a nice weekend. We've got a small manufacturing problem to tackle today. We need to get some detailed information on the assembly of one of our special faucets."

Diane: "That's right Al. We've gotten a special order for part 776-A from one of our best customers. They need 10,000 of them and we need to get them a quote on the price as soon as possible."

Russ: "Just to refresh your memories, part no. 776-A is an older faucet that we only produce to fill special orders. The last time we produced a run of these faucets the assembly required took a long time because there were many separate components. Once we got this new order, our engineers revised the design and now it requires fewer components so it shouldn't take as much time to assemble each piece."

Fred: "My department on the factory floor has assembled most of the 776-A in the past. And we'll be handling this order as well. Roy here is one of the guys who assembled that part the last time we had an order for them."

Roy: "I worked in assembly during the last order and became real familiar with how to build the 776-A. Me and Fred have gone over the new design and I think I really know the new assembly procedure well."

Al: "Ok, so what we need is some data on this new assemble procedure. If we can get a time standard on it, we can estimate production run time, manufacturing costs, and hopefully we'll be able to give our customer a fair and accurate quote."

Guide: "Al now turns and addresses you specifically."

Al: "I'd like you to be in charge of determining the time standard for this assembly procedure. Don't worry about whatever else you have to do today. With your background this should be right up your alley. Doing a time study of the assembly operation is probably the best way to find out the standard. Let me know when you've got an answer. Ok folks, that's all, thanks for coming."

Guide: "The meeting adjourns. As you have just heard, Al has instructed you to perform a time study on the new assemble operation of part 776-A. If you are still a little rusty or even totally unfamiliar with how to perform a time study, don't worry about it, back in your office you've got a collection of books that cover all aspects of time study analysis."

The learner now returns to his/her office and views the bookshelf as seen in Figure 6.

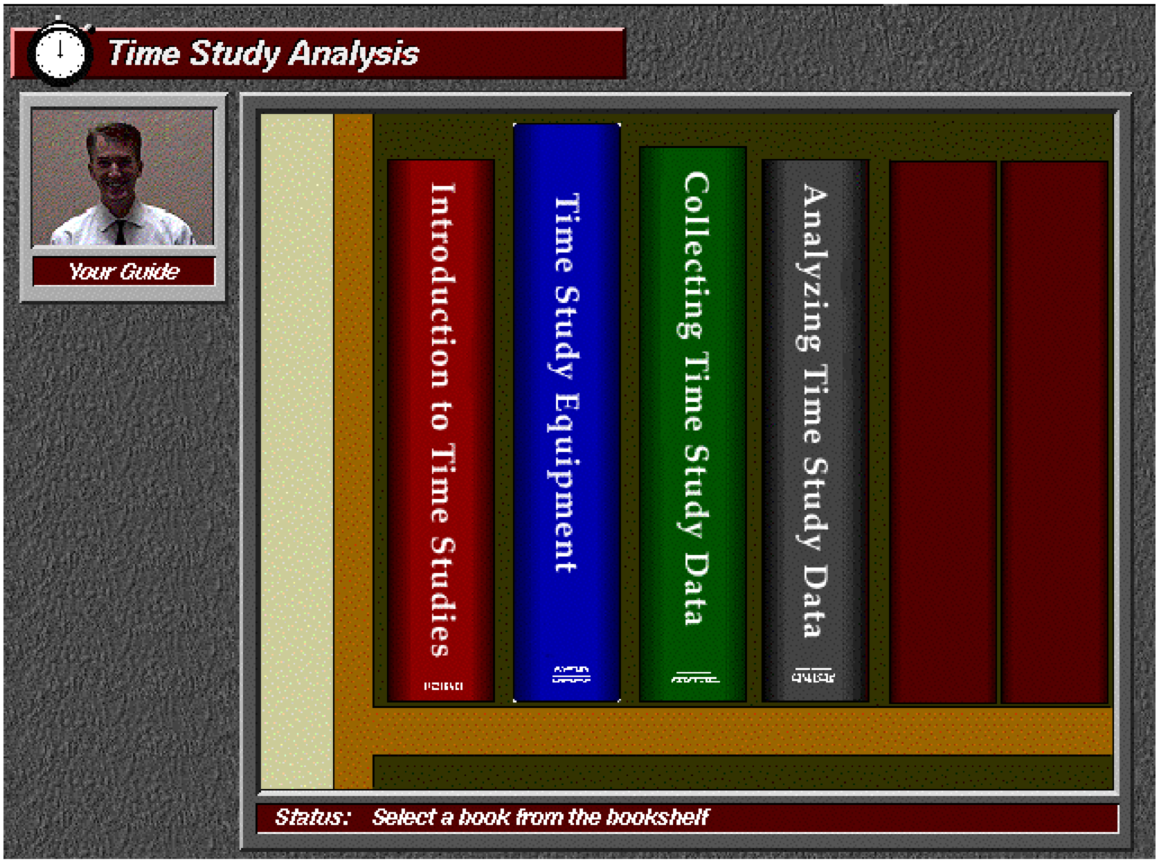


FIGURE 6 Bookshelf metaphor for simulation multimedia instruction

Book 1: Introduction to Time Study Analysis

Guide: "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

[next screen]

Guide: "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]

Guide: "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

Book 2: Time Study Equipment

Guide: "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]

Guide: "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]

Guide: "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]

Guide: "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]

Guide: "A pencil. You'll need 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.

Book 3: Collecting Time Data

Guide: "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]

Guide: "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]

Guide: "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]

Guide: "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]

Guide: "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]

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

Display: Animation of elements listing themselves on a blank Form 7. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Guide: "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 of 60 cycles for .5 minutes highlighting itself. Also list step in bulleted text in upper left corner of presentation area.

[next screen]

Guide: "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.

Book 4: Analyzing Time Data

Guide: "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]

Guide: "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]

Guide: "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]

Guide: "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]

Guide: "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]

Guide: "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]

Guide: "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]

Guide: "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 E

Instructions for Experiment

Instructional Methods Research Study

Instructions

Thank you for agreeing to participate in this experiment. The experiment is being conducted by Theresa Ramsey under the supervision of Dr. C. Patrick Koelling, an associate 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 be given instructional material to review followed by a written test. You will have a maximum of 2 hours to go through the instructional material and 1 hour to complete a test following your review of the material.

The first session of the experiment will take approximately two hours, and you will be paid $7.00 per hour for your participation. Once you have read this sheet and signed the informed consent form you will be ready for the experiment.

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.

A second session will be held two weeks after the first session. During the second session, you will complete another written test on the material. You will have a maximum of 1 hour to complete the second test.

The data will be analyzed about a month after all data has been collected. The results will 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.

Appendix F

Informed Consent Form

Participant's Informed Consent Form

Title of Project: The Effects of Instructional Method on Learning

Principal Investigator: Dr. C. Patrick Koelling
Graduate Assistant: Theresa Ramsey

Purpose of the Research Project

You are invited to participate in a study about the effectiveness of different methods of instruction. Thirty participants will be take part in this study.

Procedures

You will be given a set of instructional materials and asked to review them as though you were studying for a test. In fact, when you have finished reviewing the materials you will be asked to complete a written test to see how much you have learned. You will have a maximum of 2 hours to review the instructional materials, and a maximum of 1 hour to complete the test. You will also take a second test two weeks after the first session. You will have a maximum of one hour to complete the second test.

Risks

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, leave a self-addressed envelope.

Anonymity and Confidentiality

The results of this study will be kept strictly confidential. 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

You will receive $7.00 per hour for participation. You will be paid after the completion of the second session of the experiment.

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 time of the study.

If the investigator determines from the pre-study questionnaire that you are not suitable as a subject for this experiment, you will be compensated for the portion of the project completed.

Approval of Research

This project has been approved, as required by the Institutional Review Board for Research 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. I voluntarily agree to participate in this study.

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 project.

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

_________________________________   __________________________
Signature   Date

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

Theresa Ramsey, graduate research assistant (540) 231-5359

Dr. C. Patrick Koelling, Virginia Tech Faculty Member (540) 231-7286

Tom Hurd, Chair, IRB Research Division (540) 231-5281

Appendix G

Test Form A

Introduction to Time Study Analysis -- Test Form A

Part 1: Short Answer

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

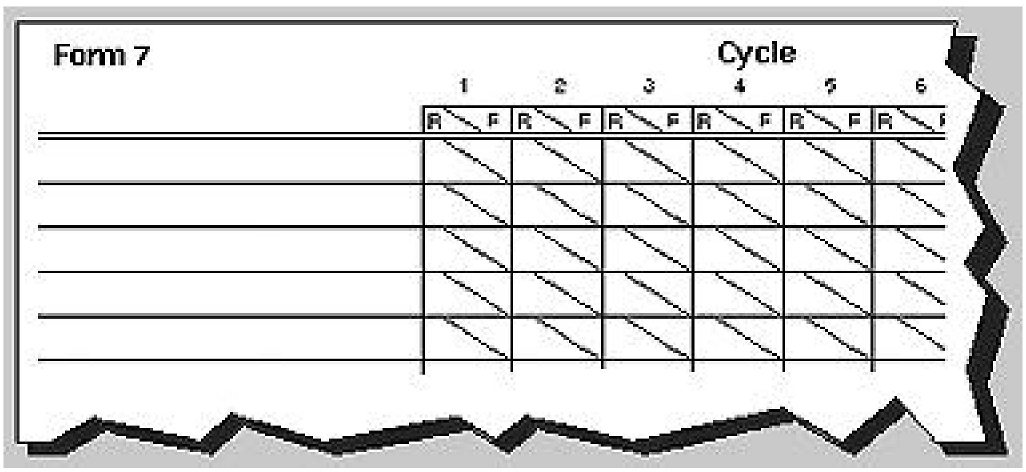
1. There are two main reasons for performing a time study. What are they?

2. What is the definition of a *time standard*?

3. 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.

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

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



Introduction to Time Study Analysis -- Test Form A

Part 2: Multiple-Choice

6. 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 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 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.

7. 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.

8. 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.

9. 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.

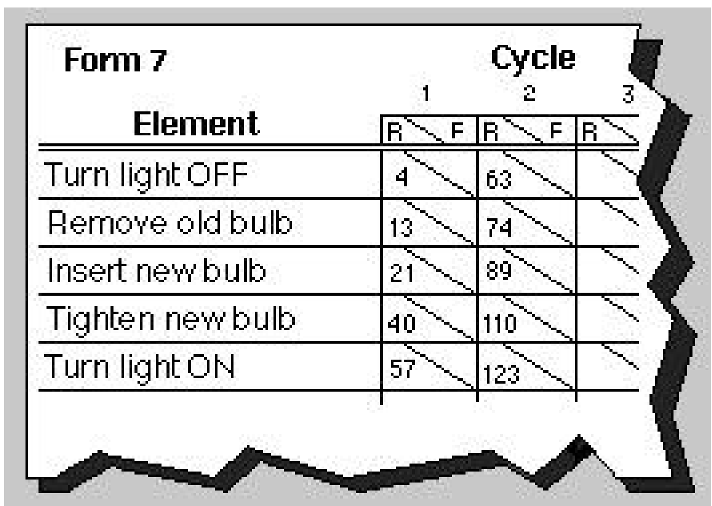
D. (1) list the element times in ascending order, (2) adjust the data for outliers using the Dixon Test, (3) calculate each average element time, and (4) calculate the time standard.

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.

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.

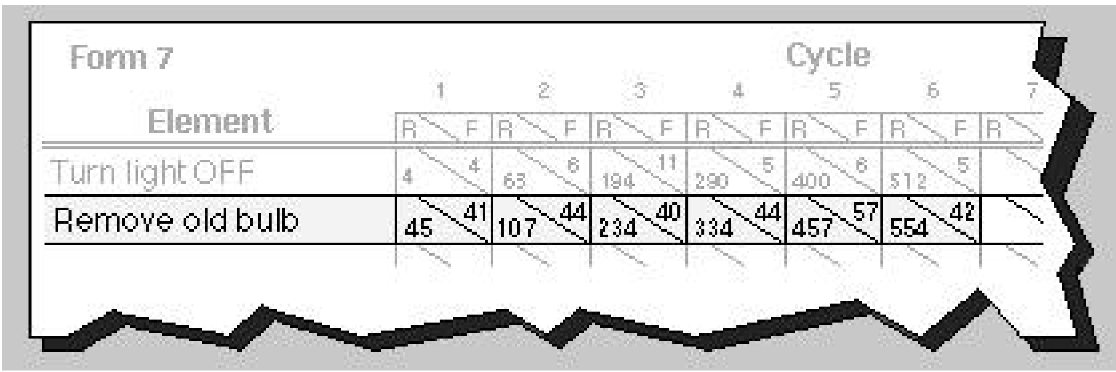
10. Suppose you performed a time study on the operation of changing a light bulb. The figure below shows a sample set of time data for 2 cycles of the job. Calculate the individual element times and record them in the appropriate cells on the Form 7.



Form 7

Element	Cycle 1 R	Cycle 1 F	Cycle 2 R	Cycle 2 F	Cycle 3 R
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		

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



Form 7

Element	Cycle 1 R	1 F	2 R	2 F	3 R	3 F	4 R	4 F	5 R	5 F	6 R	6 F	7 R	7 F
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		

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

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

12. 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.

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

Appendix H

Test Form B

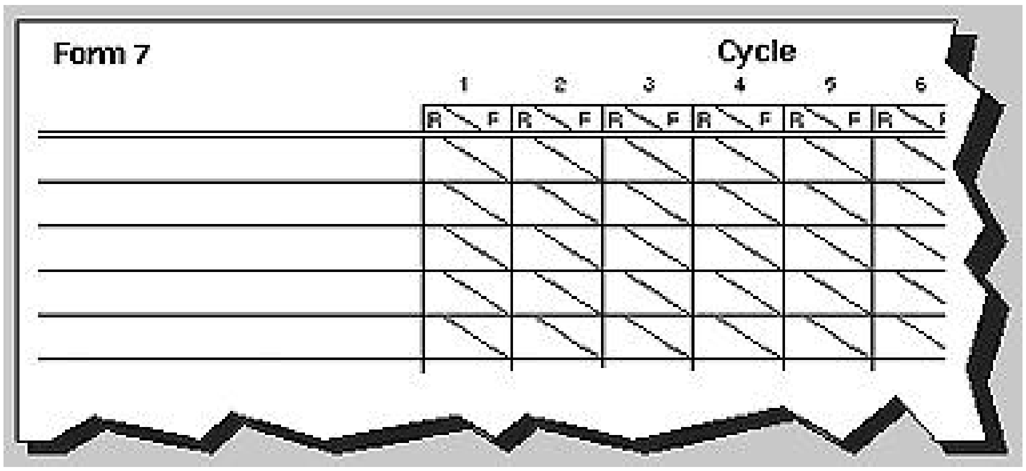
Introduction to Time Study Analysis -- Test Form B

Part 1. Short Answer

1. What are the two main reasons for performing a time study?

2. What are the four basic items of equipment used to collect time data?

3. Label the following parts of the sample Form 7 below:
A) cells for recording net element times,
B) cells for listing job elements, and
C) cells for recording elapsed times.



4. What is a time standard?

5. What quality should the worker you choose to observe for a time study possess that would make him or her a good choice?

Introduction to Time Study Analysis -- Test Form B

Part 2: Multiple-Choice

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

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

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

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

   D. Discuss the number of cycles to observe with the operator you have chosen to observe since he or she is the real expert on how the job is done.

   E. Discuss the number of cycles to observe with shop floor supervisors to get their opinion since they know the operation well.

Part 3: Number steps in the correct order.

7. Number in order the six basic steps involved in collecting time data for a time study:

______ break down the job into individual elements

______ record the time data

______ familiarize yourself with the job

______ select a worker to observe

______ determine the minimum number of cycles to observe

______ list individual job elements on the Form 7 data sheet

8. Number in order the four basic steps in analyzing time data:

______ calculate each average element time

______ calculate the time standard

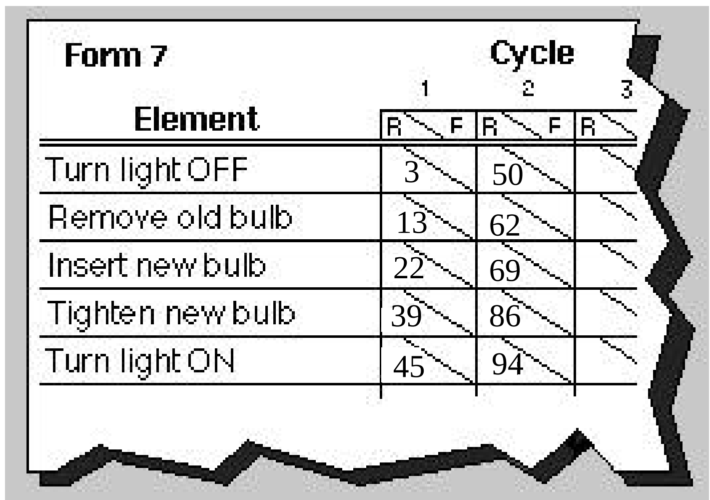
______ adjust the data for outliers using the Dixon Test

______ calculate the individual element times

Part 4: Problem-Solving

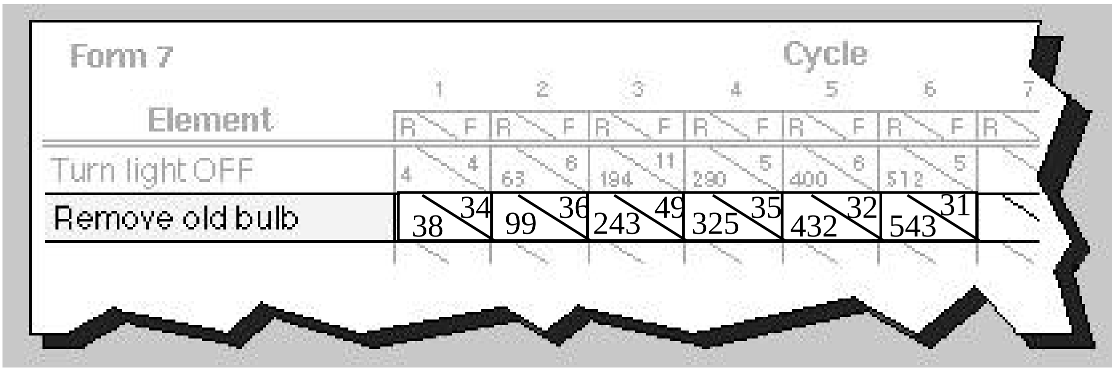
You may use the calculator and any tables or figures provided to aid you in solving each problem. Please show all your work, since your method and approach to solving the problem is just as important as coming up with the correct answer.

9. 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
Turn light OFF	3		50		
Remove old bulb	13		62		
Insert new bulb	22		69		
Tighten new bulb	39		86		
Turn light ON	45		94		

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



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

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

11. 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.

Number of cycles originally observed: 6

Number of elements in operation: 5

Average element times:	**Turn Light OFF**	5.3	sec
	Remove old bulb	12.4	
	Insert new bulb	18.7	
	Tighten new bulb	10.5	
	Turn light ON	4.7	

Appendix I

Answer Key for Test Form A

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

Part 1: Short Answer

1. 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."

3. 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.

3. 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."

4. 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)*

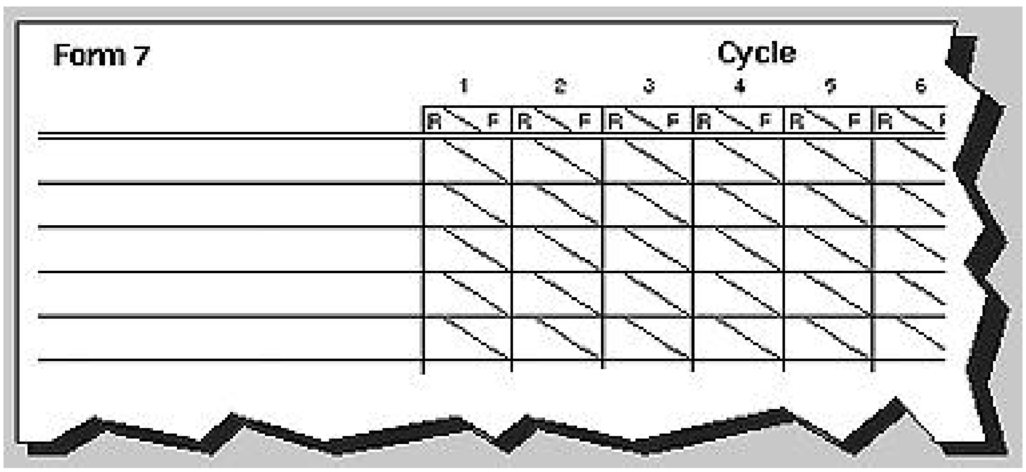
3 points awarded for "stopwatch"

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"

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

Part 2: Multiple-Choice

(Each multiple choice question is worth 12 points, no partial credit will be given.)

6. 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.

7. 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.

8. 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.

9. 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.

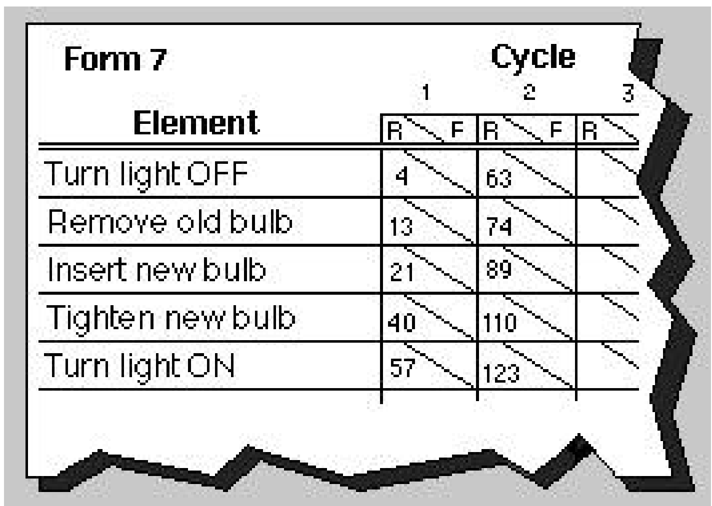
E. (1) calculate the individual element times, (2) adjust the data for outliers using the Dixon Test, (3) calculate each average element time, and (4) calculate the time standard.

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.

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.

10. 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

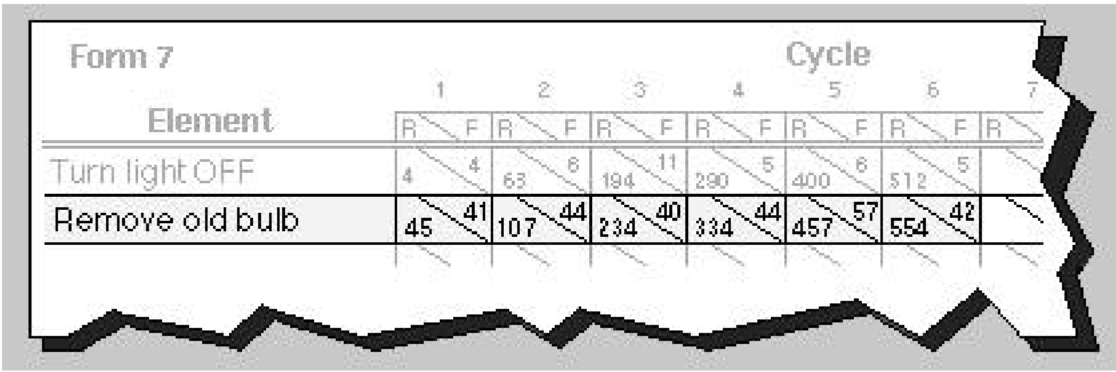
Element	Cycle 1 R	Cycle 1 F	Cycle 2 R	Cycle 2 F	Cycle 3 R
Turn light OFF	4		63		
Remove old bulb	13		74		
Insert new bulb	21		89		
Tighten new bulb	40		110		
Turn light ON	57		123		

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

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



Form 7

Element	Cycle 1 R	1 F	2 R	2 F	3 R	3 F	4 R	4 F	5 R	5 F	6 R	6 F	7 R	7 F
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		

a. 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

b. From your adjusted data set, calculate the average time to complete the element "Remove old bulb." *(25 possible points)*

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)

12. 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 J

Answer Key for Test Form B

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

Part 1. Short Answer

1. What are the two main reasons for performing a time study? *(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."

2. What are the four basic items of equipment used to collect time data? *(12 possible points)*

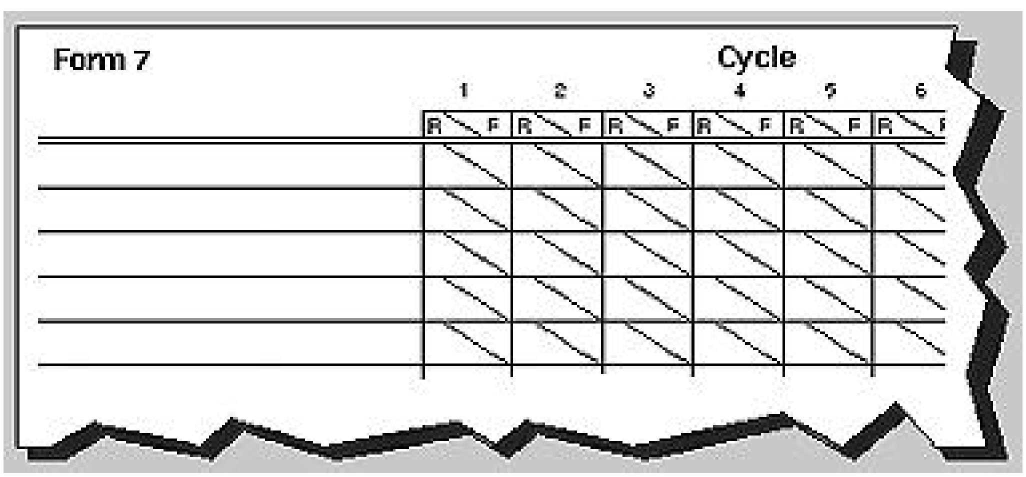
3 points awarded for "stopwatch"

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"

3. Label the following parts of the sample Form 7 below:
   A) cells for recording net element times,
   B) cells for listing job elements, and
   C) 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

4. What is 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.

5. What quality should the worker you choose to observe for a time study possess that would make him or her a good choice? *(13 possible points)*

4 points awarded automatically

4 points awarded if response included reference to "average worker"

5 points awarded if response included statement "should work at a normal pace"

Part 2: Multiple-Choice
(Each multiple choice question is worth 13 points, no partial credit will be given.)

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

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

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

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

   D. Discuss the number of cycles to observe with the operator you have chosen to observe since he or she is the real expert on how the job is done.

E. Discuss the number of cycles to observe with shop floor supervisors to get their opinion since they know the operation well.

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

Part 3: Number steps in the correct order.

(Numbering questions are worth 13 points each, no partial credit is given.)

7. Number in order the six basic steps involved in collecting time data for a time study:

___*3*___ break down the job into individual elements

___*6*___ record the time data

___*2*___ familiarize yourself with the job

___*1*___ select a worker to observe

___*5*___ determine the minimum number of cycles to observe

___*4*___ list individual job elements on the Form 7 data sheet

8. Number in order the four basic steps in analyzing time data:

___*3*___ calculate each average element time

___*4*___ calculate the time standard

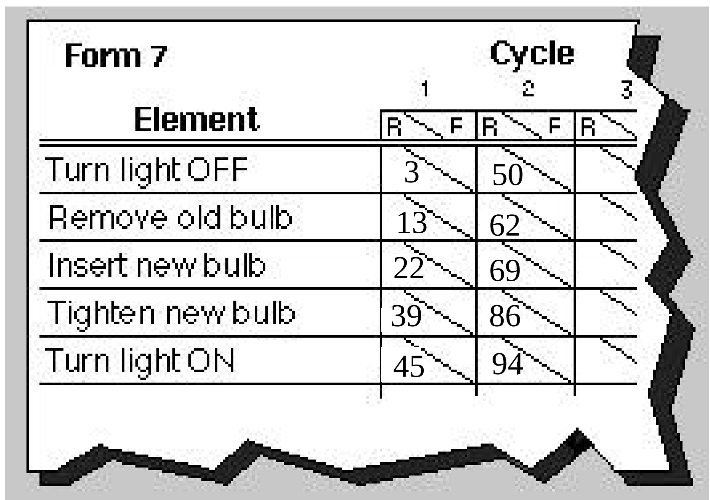
___*2*___ adjust the data for outliers using the Dixon Test

___*1*___ calculate the individual element times

Part 4: 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.

9. 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

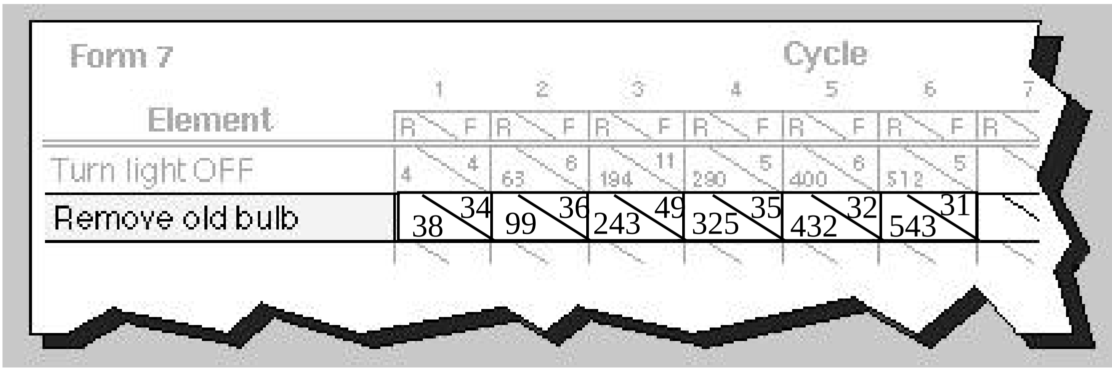
Element	Cycle 1 R	Cycle 1 F	Cycle 2 R	Cycle 2 F	Cycle 3 R
Turn light OFF	3		50		
Remove old bulb	13		62		
Insert new bulb	22		69		
Tighten new bulb	39		86		
Turn light ON	45		94		

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

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



a. 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

b. From your adjusted data set, calculate the average time to complete the element "Remove old bulb." *(25 possible points)*

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)

11. 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**	5.3 sec
	Remove old bulb	12.4
	Insert new bulb	18.7
	Tighten new bulb	10.5
	Turn light ON	4.7

5 points awarded automatically

10 points awarded for demonstrating proper calculation procedure

10 points awarded for determining the correct time standard

VITA

Theresa D. Ramsey received a B.S. degree in Management Science from Virginia Tech in 1990. She worked for Software Technologies Laboratory in Blacksburg, Virginia for five years before attending graduate school.

During graduate school, Ms. Ramsey worked as a graduate research assistant. She served as president for the Virginia Tech Human Factors and Ergonomics Society Student Chapter in 1995.

Ms. Ramsey will work for IBM in Research Triangle Park, North Carolina as a human factors engineer. Her interests include software design and usability.