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Worked examples : effect of modified and conventional worked examples on assembly time, accuracy, and efficiency in a manufacturing environment

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WORKED EXAMPLES:

EFFECT OF MODIFIED AND CONVENTIONAL WORKED EXAMPLES ON ASSEMBLY TIME, ACCURACY, AND EFFICIENCY IN A MANUFACTURING ENVIRONMENT

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This dissertation, written under the direction of the candidate's dissertation committee and approved by the members of the committee, has been presented to and accepted by the Faculty of the School of Education in partial fulfillment of the requirements for the degree of Doctor of Education. The content and research methodologies presented in this work represent the work of the candidate alone.

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STATEMENT OF THE PROBLEM

In an increasingly competitive global manufacturing environment, organizations cannot realize their competitive advantage without maximizing their in-house employee skills training and performance improvement efforts. Many companies now recognize the strategic advantage of training rather than the worn perception of it as a tactical response. The current rise in the perceived significance of training is not localized to only U.S. companies. On the contrary, industrially-advanced and advancing companies across many global regions are now stressing the development of competitive advantage through training. Arguably, in the current period of remarkable global change where there is an imperative to focus on high value-added products; workforce quality is of central importance to an organization's economic success (Crouch et al., 1997).

According to its 2005 State of the Industry Report, the American Society for Training and Development (ASTD, 2005) reports that U.S. organizations are investing more in employee learning—32 hours of learning per employee in 2004, up from 26 hours in 2003 at, of course, an increased cost. The recent ASTD (2006) report also states that most organizations train about 78% of their employees with the bulk of that training focused on technical accuracy (37%) and quality, competition, and business practices account for an additional 13% of training expenditure. This prodigious investment in training is testament to the significance now attributed to it as a primary source of competitive advantage.

What is more remarkable about recent ASTD (2006) research is the significance attributed to training by leaders at the top of some of the world’s largest and most competitive corporations. Not only are top organizational leaders cognizant of the significance of employee training to their organization’s competitive advantage, they are also aware that their organization’s training must be impeccably effective. This new premium placed on the training function underscores the need for the education field, as the parent of industrial training, to reexamine the current models of learning, especially instructional design, within naturalistic settings such as the workplace. In the face of increasing global competition, and the rise in employee development expenditure by organizations, the need to discover the most effective and efficient training approaches is quite conspicuous.

As manufacturing organizations chart the new territory of the global marketplace and strive for competitive advantage and performance excellence, the realm of training and instructional design becomes the bellwether of future success. In a recent ASTD/IBM study (2005) of 26 executives across 11 industries, results showed that training is perceived as an essential enabler of business success. According to the findings, “learning is seen by senior executives to have a significant impact on a number of business outcomes, including revenue, productivity, turnover, and innovation” (p. 56). The stated implication is that learning governance now is seen as the primary mechanism for aligning performance with strategic business objectives. The strategic placement of learning governance at the top of organizational hierarchies is both a strategic reframing and calculated restructuring of what used to be training and development. Ostensibly, effective employee skills training remains an integrally important element in learning governance of early twenty-first century companies across sectors. Ensuring the effectiveness of training now becomes an even more important factor than in years past.

Current methods for evaluating the effectiveness of industrial-use training were proposed nearly a half century ago by Kirkpatrick (1959) and consisted of four essential levels: reaction, learning retention, behavior and results. The first level measures the satisfaction of the trainee with the instructional delivery. The second measures the skill and knowledge acquired. The third level measures the effect of the training on job performance. The fourth and final level measures the effect of the overall training related to the organization’s performance. Jack Phillips added a fifth element to accommodate the advancement of technology into the learning environment (Mahapatra & Lai, 2005). The objective of measuring this fifth level is to assess the ease-of-use and relevance of utilized mediums in the training effect. Implicit in this evaluative framework is the multifocal perspective of assessors. Interested parties to training include the trainee, the trainer, the instructional designer, the employees’ managers and the organization itself.

The subject of evaluating training effectiveness has received generous attention recently (Holton, 2003; Holton & Baldwin, 2000; Kraiger, 2002; Mahapatra & Lai, 2005; Noe & Colquitt, 2002; Torres & Preskill, 2001). The majority of the training effectiveness literature is consistent with Kirkpatrick's original framework (Baldwin et al., 2000; Kraiger, 2002; Tannenbaum et al., 1993). However, over the past decade effectiveness has become refocused on determining how and why training works. For example, Blickensderfer et al. (2000) examined task experience and Schraagen et al. (2002) examined cognitive task procedures to understand the mental processing involved in learning job tasks. While some of the focus of cognitive functioning literature uses cognitive load theory and is germane to the present study, cognitive function aspects of instructional design remain largely the purview of the education field.

A basic assumption of the instructional design literature in education is that cognitive load has an influence on task learning (Leahy & Sweller, 2004; Renkl & Atkinson, 2003; Merrienboer & Sweller, Paas et al., 2003). Cognitive load theory (CLT) predicts that learners allocate limited cognitive resources, through working memory, during the processes of learning and that working memory is strictly bound and too many cognitive activities burden this limited capacity (Clark, Nguyen, & Sweller, 2006; Kalyuga & Sweller, 2004). Learners can only process a certain amount of information before becoming overloaded (Sweller et al., 1998). Cognitive load imposed on learners by processing instructional material is thought to increase when instructional design strategies split the learner's attention between text materials and other devices such as graphics (Kalyuga & Sweller, 2004).

Researchers have identified three categories of cognitive load: intrinsic, extraneous and germane (Paas, et al., 2003). According to Paas and colleagues, intrinsic cognitive load results from the interactivity between instructional elements imposing too severe demands on working memory. The second category of cognitive load occurs when unnecessary instructional elements split the attention of the learner between text and graphics and forces the learner's attention causing extraneous cognitive load. The third category, germane cognitive load, occurs because working memory resources are utilized in schema acquisition.

Cognitive load is important to training research for two reasons. First, the working memory has a limited amount of space and may not be able to hold the information that is required for learning (Sweller, 2003) and second, a common instructional design feature of training materials is the worked example (Kalyuga & Sweller 2004). Worked examples are instructions using text and/or graphics to display the work that is required to complete the task. There are several types of worked examples. The first type of worked example is separated text and graphic needed for completion of the task which may lead to an increase cognitive load by splitting attention between the text and the graphic. The second type of worked example is where the text and graphics are integrated, which may reduce cognitive load (Sweller, Van Merrienboer, & Paas, 1998).

While significant attention has been paid to cognitive load, very few researchers have explored the effects of split-attention until quite recently

(Kalyuga & Sweller, 2004; Sweller, 1999). Several studies conducted during the 1990's (e.g. Anderson et al., 1990; Carroll, 1994; Cooper & Sweller, 1987; Paas, 1992) found that while worked examples mitigate some effects associated with cognitive load, worked examples may result in a split-attention effect. Additionally, recent reviews of the literature indicate that with development of knowledge in a domain, procedures and techniques such as worked examples often became redundant and actually increase cognitive load (Kalyuga & Sweller, 2004).

Despite the empirical corroborations of the efficacy of worked examples in mitigating some cognitive load effects, and the need for integration of text and graphic portions of instructional materials (Kalyuga & Sweller, 2004; Merrienboer & Sweller, 2004) there is a significant deficiency in the instructional design knowledge base related to learning in organizational settings.

This research study addressed the deficits in the instructional design and organizational training literature related to cognitive load, split-attention, and worked examples by testing conventional and modified worked examples in use by assembly workers in a semiconductor manufacturing environment. The target population for this quasi-experimental comparative study consisted of assembly workers in a manufacturing site in Fremont California.

The typical instructional material provided to the assembly workers, presented as worked examples, forces these learners to split their attention between text and graphics when that material incorporates both devices. The workers, as learners, are required to interpret the text and graphics separately and then mentally integrate them into working memory before the instructional material can be useful. Meaning can be derived from neither the graphics nor text until after the instructional materials have been mentally integrated into working memory (Chandler, 1996; Kalyuga & Sweller, 2004; Mayer, 1999; Mayer & Moreno, 2003; Paas, 2003; Tversky, 1996). If the two sources of information, text and graphics, are complex, then an increase in cognitive load may occur (Sweller, 1998; Kalyuga & Sweller, 2004, Mayer & Jackson, 2005).

Kalyuga, Chandler, and Sweller (1998, 2000, 2001), Kalyuga, Chandler, Tuovinen, and Sweller (2001), and Tuovinen and Sweller (1999) found that procedures and techniques designed to reduce working memory overload, such as integrating textural explanations into diagrams to minimize split attention or using worked examples to increase levels of instructional guidance, were most efficient for less knowledgeable learners. With the development of knowledge in a domain, such procedures and techniques often became redundant, resulting in a negative rather than positive or neutral effect. These redundant sources of information were hypothesized to have imposed an additional cognitive load for low knowledge learners. Knowledgeable learners with acquired schemas in a specific area who try to learn new information in the same area find it more difficult to process diagrams with explanations than diagram-only formats because of the additional unnecessary information. McNamara, Kintsch, Songer, and

Kintsch, (1996) obtained clear evidence to the expertise reversal effect although they did not interpret their results in a cognitive load framework.

Why do experienced learners with worked examples result in a reduction in performance compared with reduced instruction? Constructing integrated mental representations of a current task is likely to require a considerable share of working memory resources. This activity may be supported either by available schema-based knowledge structures from long-term memory or by external instruction. For novices learning new information, instruction may be the only available source to understanding. For experts dealing with a previously learned familiar domain, appropriate schema-based knowledge can carry out necessary control and regulation functions for the task. Human cognitive architecture dramatically alters the manner in which information is processed as that information increases in familiarity (Sweller, 2003). If more knowledgeable learners are presented instruction intended for schema construction purposes, that redundant instruction may conflict with currently held schemas, resulting in the redundancy and expertise reversal effects. The optimization of cognitive load in instruction assumes not only the presentation of appropriate information at the appropriate time but also timely removal of inefficient, redundant information as learner levels of knowledge increase.

The modified worked example is a presentation of information where text and graphics are integrated as compared to a conventional worked example that has text and graphics in two disparate places. The purpose of the modified worked example is to reduce the cognitive load for the learner. The conventional worked example is designed without the integration of text and graphics. Without integrating text and graphics in the modified work example, the learner may experience an increase in cognitive load.

Purpose of the Study

Consequently, the purpose of this study was to compare two types of worked examples, conventional worked example (CWE) and modified worked example (MWE). The (CWE) was designed with the text and graphics in two disparate places while the (MWE) was designed with the text and graphics integrated. Research subjects were assigned to the groups and then asked to complete the job tasks within a prescribed time using the worked examples. When subject's completed the job tasks, they were assessed for their assembly time, error rate, and ability to complete the job.

This study used a sample drawn from a population of manufacturing workers (N = 54) within a contract manufacturing firm serving the semiconductor manufacturing sector. The firm is located in the Silicon Valley of California. The subjects in this study are assemblers and have been assembling with this manufacturing company from 6 months to over 3 years. This study differs from previous research because it was conducted on-site in a manufacturing company using actual assemblers' as subjects. These assemblers do not differ from other assemblers in manufacturing companies because they use an engineering drawing, which is similar to a worked example but is more detailed about an entire unit, rather than just a worked example that is oriented around one-step.

Significance of the Study

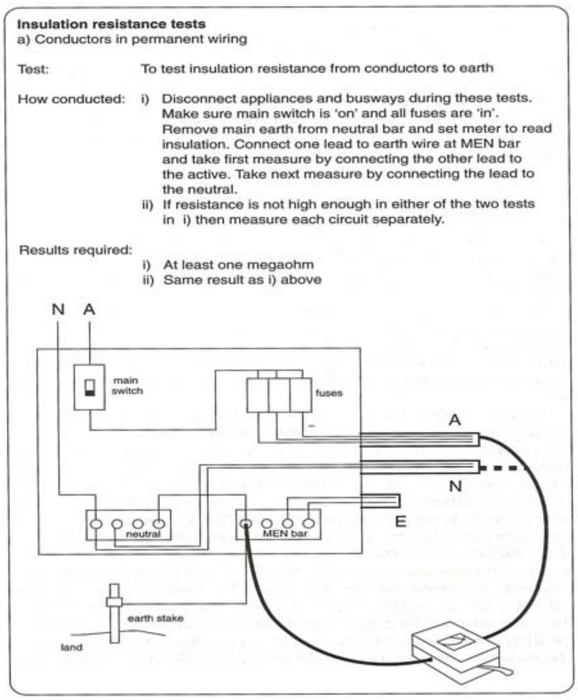
There are several reasons why this study is important. First, no one has conducted a study on the use of worked examples in a manufacturing environment using assemblers as subjects. Second, with the exclusive use of a conventional worked example, there are no data to support or deny if either conventional or modified worked examples would be a benefit in training assemblers. Third, the use of the CWE without comparing them to MWE is of little or no use to support improvement of the MWE. Finally, no body of research exists that provides data indicating whether CWE or MWE is superior in performance, reduction in assembly time and a reduction in errors in the finish product. Current experts in the field recommend that research be conducted in a variety of settings with various learners (Kalyuga & Sweller, 2004).

Theoretical Rationale

Conventional worked examples (CWE) are developed with text, graphics, or a combination of both as a “stand-alone” instruction. A CWE is a work instruction that is written in text and pictures or drawings to describe a process for building a product. A typical text instruction on a conventional worked example might read as in figure 1, for insulation-resistance tests.

Modified worked examples, (MWEs) are worked examples that are designed with text and graphics integrated.

Figure 1. Conventional worked example[1]



When the learner views the graphic in Figure 2, and finds they are unable to solve the problem with the graphic presented, the learner will search for additional information. If the learner looks at the graphic Figure 2 presents the same instruction as the conventional worked example in Figure 1, except it has been modified so that the text and graphic are integrated.

prior to reading the text, the learner may not be able to perform the test because the graphic makes no sense until the text has been integrated; hence, the learner

[1] From "Instructional Design in Technical Areas" by J. Sweller, *Experimental evidence using electrical engineering processes*, p.120. Copyright 1999 by The Australian Council for Educational Research Ltd.Reprinted with permission of the author.

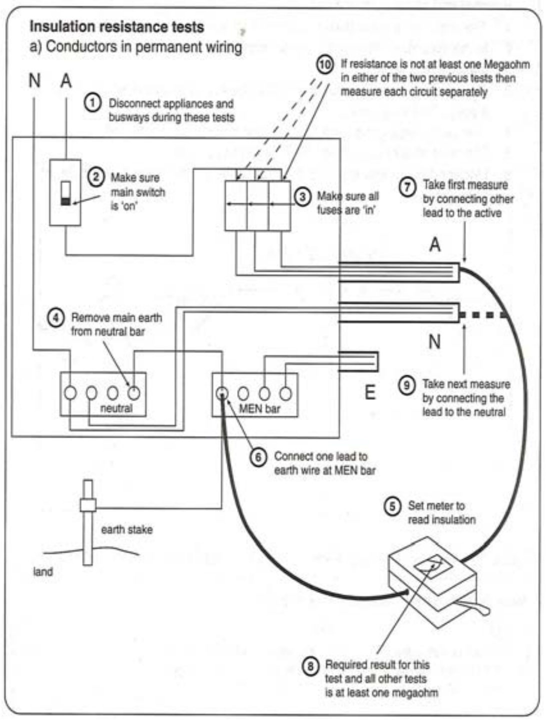
must use additional cognitive resources to engage in the process of integration before proceeding with the test.

Several elements of information are required on a worked example to assist the technician to test the insulation-resistances successfully. When reading the worked example, the learner then may find the pieces of information overwhelming and find it difficult or impossible to interpret the instructions, which could result in overloading the working memory. Worked examples are self-contained and require little or no instruction about their use. The text on a CWE is written without engineer terminologies that include how the sequencing is to be done. This conventional worked example requires the learner to first read the test and then look at the graphic to explain visually the test procedure. The learner may have to search for additional information on the worked example, which would increase the cognitive load. After reviewing the graphic, the learner may have to read the text several times before the text and graphic are integrated. The instructional developer of this example elected to place the text at the top and the graphic at the bottom, which requires the learner to read the text first then look at the graphic. By separating the text and graphic, the learner may experience an increase in cognitive load and may not be able to determine what is expected after reading the text and comparing it to the graphic.

In Figure 2, the worked example presents the information integrated rather than in separate sections as in the first example. There is no need for the learner to search for additional information because the information has been integrated.

When the text and graphic are integrated, a reduction in cognitive load may be possible, thereby reducing the split-attention effect. Too many elements can overwhelm working memory and increase cognitive load, which may decrease the effectiveness of instruction.

Figure 2. Modified worked example[2]



Cognitive load theory suggests that effective instructional material facilitates learning by directing cognitive resources toward activities that are relevant to learning rather than toward preliminaries to learning (Kalyuga & Sweller, 2004).

[2]From "Instructional Design in Technical Areas" by J. Sweller, *Experimental evidence using electrical engineering processes*, p.121. Copyright 1999 by The Australian Council for Educational Research Ltd. Reprinted with permission of the author.

The guidelines for cognitive load are designed to facilitate the presentation of information in a manner that encourages learners to use work examples to improve their performance.

Current research indicates that the level of expertise of the learner is important to the structure of the instructional design (Kalyuga & Sweller, 2004). Novices might require the graphic to be integrated physically with related text-based information in order to reduce the cognitive load. However, the same graphic might be intelligible in isolation by more experienced learners, who might require the elimination of a redundant cognitive load (Kalyuga et al., 1998). The cognitive load can be determined by the limited working memory. Limited working memory is one of the defining aspects of human cognitive architecture and, accordingly, all instructional design should be analyzed from a cognitive load perspective. Many commonly used instructional designs and procedures are designed without reference to working memory limitations (Mayer, 1991; Sweller & Chandler, 1992).

Studies using worked examples demonstrate that when learners use modified worked examples, performance improved compared to personnel who used the conventional worked examples. Several findings suggest the effectiveness of solving large numbers of conventional problems increases the cognitive load more. Modified worked examples reduce the learner's cognitive load (Cooper & Sweller, 1987). It has been proposed that instructional design, working memory, and cognitive load are all factors in developing work examples that may improve performance (Sweller & Chandler, 1991). It is appropriate to ask the question whether modified worked examples would help learners. Additional theories in cognitive science, dual channel assumption, limited capacity assumption, and active processing assumption guide the present research and are discussed next.

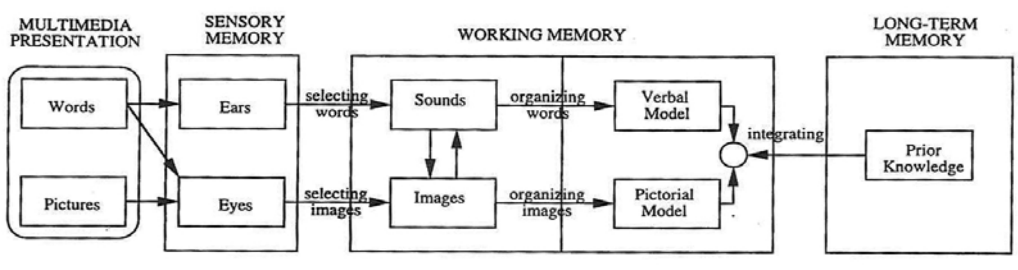
First, the human information processing system consist of two separate channels an auditory/verbal channel for processing auditory input and verbal representations and a visual channel for processing visual input and pictorial representations. Based on research on discourse processing (Graesser, Millis, & Zwaan, 1997), to equate verbal channel with an auditory channel would not be appropriate since Mayer (2005) provided an extended discussion of the nature of dual channels. The dual-channel assumption is a central feature of Paivio’s (1986) dual-coding theory and Baddeley’s (1998) theory of working memory, although not all theorists characterize the subsystems similarly (Mayer, 2005).

Second, each channel in the human information processing system has limited capacity, only a limited amount of cognitive processing can take place in the verbal channel at any one time, and only limited amount of cognitive processing can take place in the visual channel at any one time. This is the central assumption of Chandler and Seller’s (1991; Sweller, 1999) cognitive load theory and Baddeley’s (1998) working memory theory.

Third, meaningful learning requires a substantial amount of cognitive processing to occur in the verbal and visual channels. This principle forms the basis of Wittrock's (1989) generative-learning theory and Mayer's (1999) selecting, organizing, integrating theory of active learning. These processes include paying attention to the presented material, mentally organizing the presented material into a coherent structure, and integrating the presented material with existing knowledge.

Another relevant theory, the theory of multimedia learning, figure 3 below, is significant to the present study. The cognitive model of multimedia learning is intended to represent the human information processing system (Mayer, 2001). The two rows of boxes in figure 3 represent the two information–processing channels, with the auditory/verbal channel on top and the visual/pictorial channel on the bottom. This configuration is consistent with dual-channel assumption.

Figure 3. Cognitive Module of Multimedia Learning[3]



The five columns in Figure 3 represent the modes of physical representation (e.g., words or pictures that are presented to the learner), sensory

[3] From "*Learning*: *A Cognitive Theory of Multimedia Learning,*" *by R* Mayer, 2001, *Multimedia Learning*, p. 44. Copyrighted 2001 by Cambridge University Press. Reprinted with permission of the author.

representations (in the ears or eyes of the learner), shallow working memory representations (e.g., sounds or images attended to by the learner), deep working memory representation (e.g., verbal and pictorial models constructed by the learner), and long-term memory representations (e.g., the learner's relevant prior knowledge).

The capacity for physically presenting words and pictures is virtually unlimited, and the capacity for storing knowledge in ling-term memory is virtually unlimited, but the capacity for mentally holding and manipulating words and images in working memory is limited. The working memory columns in Figure 3 are subject to the limited capacity assumption.

The arrows in Figure 3 represent cognitive processing. The arrow from *words* to *eyes* represents printed words impinging on the eyes; the arrow from *words* to *ears* represents spoken words impinging on the ears; and the arrow from *pictures* to *eyes* represents pictures (e.g., illustrations, charts, photos, graphics, animations, and videos) impinging on the eyes. The arrow labeled *selecting words* represents the learner's paying attention to some of the auditory sensations coming in from the ears, whereas the arrow labeled *selecting images* represents the learner's paying attention to some of the visual sensations coming in through the eyes. The arrow labeled *organizing words* represents the learner's constructing a coherent verbal representation from the incoming words, whereas the arrow labeled *organizing images* represents the learner's constructing a coherent pictorial representation from the incoming images.

Cognitive activity involving text and images takes place in the working memory. Working memory is used for temporarily holding and manipulating knowledge in the active conscious. For example, in reading a sentence, the learner may be able to concentrate actively on only some of the words at one time, or to concentrate on several images. What the learner is consciously aware of is what is taking place in the working memory. Mayer points out the limitations of the two channels: “the idea is that the verbal channel is limited and the visual channel is limited so it is important not to overload either one. When you present a small amount of material to each channel (simultaneously) learners are better able to make connections between visual and verbal representations” R. E. Mayer (personal communication, November 05, 2001).

Finally, the arrow labeled *integrating* in Figure 3 represents the merging of the verbal model, the pictorial model, and relevant prior knowledge. In multimedia learning, active processing requires five cognitive processes: selecting words, selecting images, organizing words, organizing images, and integrating. Consistent with the active-processing assumption, these processes place demands on the cognitive capacity of the information processing system. Figure 3 represents the active processing required for multimedia learning.

The concept of separate information processing channels has a history in cognitive psychology and currently is most closely associated with Paivio’s dual-coding theory (Clark & Paivio, 1991; Paivio, 1986) and Baddeley’s model of working memory (Baddeley, 1986, 1992, 1999). The importance of how humans receive information from their ears and eyes and how they process that information in working memory is crucial in the development of worked examples. The cognitive model of multimedia learning model in Figure 3 is the base of developing worked examples. From these different examples, it can be seen that there are several ways in which one can process information and learn new methods. Because of this, it is important to find the most effective theory in providing learning and worked examples for learners.

According to Sweller (1999), separating the text and graphics causes the learner to split attention and may give rise to a split-attention effect. The split-attention effect is defined as any impairment in leaning that occurs when the learner must mentally integrate disparate sources of information. In the context of learning, Sweller and colleagues have demonstrated the split-attention effect from worked examples (Chandler & Sweller, 1990; Cooper & Sweller, 1987; Sweller & Cooper, 1985; Ward & Sweller, 1990). When worked examples are poorly designed, the learner must engage in irrelevant or ineffective cognitive processing. When the worked example is well designed, cognitive load is minimized (Mayer 2001).

Background and Need

The strategic purpose of employee training for organizations is threefold: enculturation, achieving high quality standards (AKA performance improvement), and increasing productivity (ASTD, 2005). The significance of training is perceivable through assessment of organizational expenditure. The cost of training in manufacturing, customer service, and sales to and supervision of personnel in the United States runs 50 to 60 billion dollars each year (Dolezalek, 2004). Given the importance of training to strategic objectives, organizations desiring to realize their competitive advantage must ensure the effectiveness of training delivery to workers. When organizations provide instructional materials that thwart learning rather than enable it, they risk severe financial loss. It is incumbent upon organizations to understand what instructional design techniques work under various circumstances.

Good instructional design is essential to learner success. Research has shown that at the beginning of the process of learning a new skill, learners are usually clumsy, error-prone and slow (Paas et al, 2003; Renkl & Atkinson, 2003; Sweller, 1999), and under certain circumstances, existing performance may suffer. For example, on a manufacturing assembly line (where a new product is to be assembled), the assembler may not have been trained to assemble the new product and therefore may not be familiar with the worked instructions. These worked instructions, known as conventional worked examples (CWE), may be confusing to the assembler (Sweller, 1999). The accuracy and speed of placing or connecting parts to a new assembly may cause the assembler problems with reading the worked instructions until he/she is able to interpret from the CWE what indeed needs to be completed.

Instruction can include multiple sources of information such as a combination of text and graphics. To understand the text and or the graphic, it may be necessary mentally to integrate them into working memory. Such mental integration is likely to impose a heavy, extraneous cognitive load (Sweller et al. 1990, 1998, 2004). The cognitive load is extraneous because it is caused entirely by the format of the instruction rather than by the characteristics of the material. A combination of difficult and heavy extraneous cognitive load, along with how the worked example was developed, may undermine learning because the working memory is exceeded substantially.

One purpose of instructional design is to provide communication in a manner that will result in others obtaining knowledge and being able to use that knowledge to carry out new tasks. Instructional design guidelines enable the instructional designer to select the best possible instructional methods, given the outcomes that instruction is intended to attain and the conditions under which instruction is to occur (Reigeluth, 1983).

Richard Mayer's cognitive theory of multimedia learning (2003) provides a background on the assumption made by an instructional designer on how human learners process information. Mayer points out that instructional designers do not take into account how human learners process information. According to Mayer, an assumption made by some instructional designers is that learners posses a single-channel unlimited-capacity and passive-processing system. This single channel assumption assumes all information enters the cognitive system in the same way regardless of its modality. Furthermore, instructional developers often assume that the cognitive processing system ahs is based unlimited capacity and that learners can handle an unlimited amount of information. The passive-processing assumption presents many isolated pieces of information that assumes the learner is a tape recorder. The implicit assumptions of this view are that the learner does not need any guidance in organizing and making sense of the presented information.

Current research in cognitive psychology shows a contrasting view of how mental processing works than what was assumed in the past (Bransford, Brown & Cocking, 1999; Lambert & McCombs, 1998; Schwartz, Bransford, & Sears, 2005). The three assumptions of Mayer's cognitive theory of multimedia learning can be summarized as follows:

1. Dual Channels: Humans' posses separate channels for processing visual and auditory information.
2. Limited Capacity: Humans are limited in the amount of information that they can process in each channel at one time.
3. Active Processing: Humans engage in active learning by attending to relevant incoming information, organizing selected information into coherent mental representations, and integrating mental representations with other knowledge.

As Schwartz, Bransford and Sears (2005) posit, much of the cognitive work involved in multimedia learning takes place in working memory. Working memory is used for temporarily holding and manipulating knowledge in active consciousness. Working memory usually is characterized as the part of our cognitive architecture in which information is undergoing active processing. This part of our cognitive architecture is considered to have only a very limited capacity. It is assumed that a mere seven chunks (plus or minus two), of information can be maintained simultaneously (Miller 1956). Not only is the storage capacity limited in working memory but its ability to process information (e.g., information that has to be compared or organized) is also restricted. Where there are multiple processing demands, working memory capacity may be limited to the simultaneous processing of two or perhaps three chunks of information.

According to Sweller (1999), *working memory* is used to process raw data in the sense of organizing, contrasting, comparing, or processing it in some manner. The number of elements from the worked example may increase the cognitive load, which may then exceed the capacity of the working memory. When learners study a worked example that presents information in the form of text and or graphics through a demonstration used to illustrate how to complete a task, they are compelled to split their attention between the text and the graphic, which increases working memory thereby increasing cognitive load because of the additional information. The difficulty with conventional worked examples is the manipulation of new information elements in working memory, i.e., the difficulty of holding and processing new information such as text and graphics in working memory (Kalyuga & Sweller, 2004; Sweller, 1999). This study will examine the efficacy of two types of worked examples.

Research Questions

The following research questions were examined in the present study.

Hypothesis H_{01}: Is there a difference in assembly time between the MWE and CWE groups?

Hypothesis H_{02}: Is there a difference in the errors between the MWE and CWE groups?

Hypothesis H_{03}: Is there a difference in tasks completed between the MWE and CWE groups?

Definition of Terms

In this study, several different terms must be defined to facilitate clarity concerning the use of the terms and the theories presented throughout the report.

Assembly: Fitting together of parts to form a complete unit (Webster's New World Dictionary, 1989).

Assembly Time: The time it takes a worker to prepare a part of the manufacturing item.

Cognitive Load Theory: the distribution and use of working memory resources during learning and problem solving. All cognitive activities will impose a cognitive load (Sweller, 1988).

Conventional Worked Example: An instructional device that has text and graphics located separately on a piece of 81/2 x 11 paper.

Error: Used in manufacturing when one more parts are not used correctly or are missing from the product.

Expertise Reversal: The negative effect of instructional methods that aid the learning of novices on the learning of experts.

Germane Cognitive Load: Work imposed on working memory that uses mental capacity in ways that contribute to learning.

Intrinsic Cognitive Load: work imposed on working memory because of the amount of element interactivity of the content to be learned.

Long-term Memory: A relatively permanent ,mental repository of knowledge and skills in the form of schema that provided the basis for expertise.

Modified Worked Examples: An instructional device that has text and graphics integrated together on a piece of 8 ½ x 11 of paper.

Parts in Motion: A visual cue made of a graphic and a solid line to indicate where the new part is to be installed.

Redundancy Principle: A cognitive load principle starting that content or content expressions that are duplications either of each other or of knowledge already in memory impede learning.

Schema: A memory structure located in ling-term memory that is the basis for expertise. Schemas can be large or small and grow over time as learning progresses.

Scorecard: A piece of paper or card that has all the movements required of the subjects' completing the product. The researcher will mark on the scorecard correct or incorrect for each movement.

Split-Attention: Instructional material that requires the learner to split their attention between multiple sources of information and then mentally integrate those sources. Split-attention is common on conventional worked examples (Sweller, 1988).

Worked Examples: A step-by-step demonstration used to illustrate how to complete a task.

Working Memory: Working memory is used for temporarily holding and manipulating knowledge inactive consciousness (Mayer, 2001).

Summary

Learners often divide their attention between text and graphics, which increase cognitive load. This splits their ability to focus by resulting in more steps for cognitive processing. They can interpret both the text and graphic; however, they also have to mentally integrate both of them while learning new methods and continuing the process. Depending on the complexity, an overload in cognition can occur. This can be particularly harmful in the manufacturing environment where mistakes can be costly and quality control is important. This research focused on experiments conducted with groups of personnel from a highly profiled company in an effort to provide an alternative to cognition overload and help designers of learning material to have further literary resources on the subject matter.

A systematic assessment of published work reveals some serious gaps in our knowledge base. Particularly, a review of the area of cognitive load and worked examples indicates that more research attention must be paid to the effects of cognitive load in the use of worked examples and resulting effects related to split-attention and learner knowledge level. Additionally, there is dearth of empirical research within naturalistic settings such as business organizations, which is attributable to the lack of knowledge sharing between fields as well as the recency of interest in the topic. Lastly, the mitigation of the learning challenges facing manufacturing organizations at present requires straightforward knowledge of specific instructional design techniques that enable learners to efficiently process and learn complex work tasks.

In the manufacturing units serving semiconductor companies, there is a need to reduce assembly time and to increase accuracy of the assembly through the provision of efficient training methods. Often in the semiconductor industry, contract manufacturers build other manufacturers’ products. The contract manufacturers provide the assemblers to assemble, test, and package another company’s product for distribution. These assembly workers regularly must learn procedures and processes associated with new product as part of new contracts.

CHAPTER II

REVIEW OF THE LITITURE

Introduction

This quasi-experimental study compared the effects of a modified worked example (MWE) with a conventional worked example (CWE) on assembly time, accuracy, and efficiency in a manufacturing environment. Specifically, this study concerns development of instructional materials for use by manufacturing assemblers in their work. To develop effective worked examples for use in manufacturing environments, instructional designers must be knowledgeable in cognitive load theory and split-attention. This chapter provides a context for the importance of this area of research, reviews relevant literature that informs the study, discusses key constructs and definitions, and highlights gaps in the literature that indicate the potential contribution of this research. In this chapter particularly, the researcher reviews the existing knowledge on cognitive load theory, split-attention, and the specific instructional design techniques of modified and conventional worked examples. Before launching into the review of the relevant topic areas, however, it is important first to briefly describe the conditions under which learning takes place.

Learners in manufacturing settings typically are forced to split their attention between text and graphics when learning from task-related instructional material. They are required to interpret the text then the graphic and mentally integrate them into working memory before the instructional material can be useful to them. Research informs us that when the two sources of information—text and graphics—are complex, an increase in cognitive load occurs (Kalyuga & Sweller, 2004; Mayer & Jackson, 2005; Mayer & Moreno, 2003; Paas et al., 2003). From the perspective of instructional design, the limited capacity of the working memory is the major restriction for designing new instruction materials (Ginns, 2005).

Sufficient research from learning psychology supports the view that working memory is used commonly to process information in the sense of organizing, contrasting, or comparing (McCrudden et al., 2004). Working memory in which all conscious cognitive processing occurs, can handle only a limited number possible no more than two or three of interacting elements (Paas et al., 2003). Long-term memory provides to increase the processing ability. Long-term memory store can contain many numbers of schemes, cognitive constructs that incorporate multiple elements of information into a single element. The number of elements or information from the worked example may increase the negative cognitive load, which may then exceed the capacity of the working memory (Paas et al., 2003). To augment the process, schemas can be imported from long-term memory into working memory. For example, whereas working memory might only deal with one element, that level may consist of a large number of lower level interacting elements. Those interacting elements may exceed working memory capacity if each element had to be processed. Their incorporation in a schema means that only one must be processed. The complex set of interacting elements can be manipulated in working memory because of schemas held in long-term memory (Kalyuga & Sweller, 2004; Paas et al., 2003: Renkl & Atkinson, 2003). Once the working memory capacity is exceeded, the learner experiences cognitive overload. While research over the past decade has advanced our understanding of how cognitive functioning either supports or hinders learning, the majority of the work has focused on learners in academic settings. Additional research in the past five years has advanced our knowledge base somewhat concerning various conditions associated with cognitive load related to instructional design; however, there is a scarcity of research concerning learner characteristics and learning environments. The following discussion presents the historical and current perspective relative to the first important topic of cognitive load.

Cognitive Load Theory

Cognitive load theory (CLT) originated in the 1980's and is concerned with the distribution and use of working memory resources during learning and problem solving. The theory is concerned with the instructional implications of interactions between information structures and cognitive architecture (Sweller, 1998). As well as element interactivity, the manner in which information is presented to learners and the learning activities required of learners can impose a cognitive load. According to cognitive load theory, there are three forms of cognitive load (Kalyuga & Sweller, 2004; Merrienboer & Sweller, 2005). The first form is the intrinsic cognitive load, that is where demands on working memory capacity imposed by element interactivity are intrinsic to the material being learned is called intrinsic cognitive load. Different materials differ in the levels of element interactivity and intrinsic cognitive load cannot be altered by instructional manipulations; only a simpler learning task that omits some interacting elements can be chosen to reduce this type of load.

The second form of cognitive load occurs when the load is unnecessary and interferes with schema acquisition, which it is referred to as an extraneous or ineffective cognitive load (Kalyuga & Sweller, 2004; Merrienboer & Sweller, 2005). An example of extraneous load would be instructional material or worked examples that might include a graph consisting of symbols and an adjacent text in which the name of each feature is associated with its appropriate symbol. Meaning can be derived from neither the graphic nor text until after they have been mentally integrated in working memory. The third form of cognitive load is germane or effective cognitive load. Importantly, the instructional designer influences germane cognitive load (Renkl & Atkinson, 2003; Sweller, 1998). The design in which information is presented to learners and the learning activities required of learners are factors relevant to levels of germane cognitive load. Whereas extraneous cognitive load interferes with learning, germane cognitive load enhances learning. Instead of working memory resources being used to engage in searching for information, as occurs when dealing with extraneous cognitive load, germane cognitive load results in those resources being devoted to schema acquisition (Chandler, 1998; Mayer, 1998; Mayer & Jackson, 2005; Mayer & Moreno, 2003; Tversky, 1996).

One primary concern of cognitive load theory is how learners will allocate limited cognitive resources during the processes of learning. The theory assumes the working memory is strictly bound and many cognitive activities place restraints on this limited capacity (Mayer & Jackson, 2005). Consequently, high-element interactivity material is difficult to understand. It turns out though; all cognitive activities will impose a cognitive load. In most learning contexts, the nature of the cognitive load will be determined in part by the presentation of instruction. For example, when material such as geometry and algebra problems are presented to learners either to learn or to manipulate, the manner in which they process the material will be heavily determined by its structure. The instructional formats will favor some cognitive activities to the exclusion of others.

Our cognitive functioning consists of a limited working memory used to learn, think, and solve problems and a large long-term memory used to store many automated schemas that can be imported into working memory for processing when required. Learning consists of the acquisition of automated schemas. The ease with which learning can occur depends on the extent to which the elements that need to be acquired interact. Cognitive load theory informs us that many commonly used instructional procedures impose a heavy working memory load that interferes with the very learning intended by the instructional procedure (Kalyuga & Sweller, 2004; Sweller, 1998). In other words, some procedures interfere with rather than assist in schema acquisition and automation. The interference of schema acquisition imposed by well-intentioned designers, unnecessarily forces learners to solve many conventionally structured problems, process material that requires mental integration of multiple sources of information, and process redundant information. Only in the past five years, have researchers begun to address the serious deficits in our understanding of the multiple affects of instructional design on learners particularly related to the knowledge and experience level of the learner.

Split Attention

Another area that increases cognitive load and may impede learning is what is known as split-attention. Researchers examining split-attention (Renkl & Atkinson, 2003; Sweller, 1988) suggest that learners studying a worked example must split their attention between text and graphics and mentally integrate them into working memory before the information can be useful. The split-attention effect has been a major problem with some instructional designs (Chandler & Sweller, 1991, 1992; Sweller & Chandler, 1992, 1994; Sweller et al., 1990; Tarmizi & Sweller, 1988; Mousavi et al., 1995). For example, when two or more related sources of information (e.g., text and graphics), requires mental integration to construct a relevant schema and achieve understanding. When different sources of information are separated in space (e.g., text located separately from a graphic) or time (e.g., text presented after or before the graphic is displayed), this process of information integration may place an unnecessary strain or limited working memory resources. Integration of the text and graphic for learning is impeded because the processes may be involved in cross-referencing the representations. This searching out the information may severely interfere with constructing integrated schemas, thus increasing the burden on working memory and impede learning.

Split attention does not depend on different forms of information such as diagrams and text or equations and text. It can occur when any two or more sources of information must be integrated mentally before they can be understood, even if those sources of information are identical in structure. For example, textual information frequently is structured in a manner such that one part of the text is intelligible only by integrating it with another part. If this split-attention format is used, it only can be understood by holding relevant components in working memory and mentally integrating them. Frequently, that means reading one section while searching another section for details of significant referents (Kalyuga & Sweller, 2004).

The activity of searching for references in a diagram, text, or asset of equations is likely to be cognitively demanding, exceeding working memory capacity under some circumstances. In addition, once the relevant section is found, the multiple sources of information (e.g. text and diagram) must be mentally integrated. Attention must not only be devoted to both sources of information simultaneously; both sources must be processed in order to effect the necessary mental integration. Furthermore, the activity of integrating multiple sources of information seems quite unrelated to schema acquisition. These learning mechanisms are likely to come into play only after the necessary integration between the disparate sources of information has occurred. Until then, cognitive activity is directed towards recasting the instructional material into form suitable for learning.

Sweller and his colleagues (Mawer & Sweller, 1982; Owen & Sweller, 1985; Sweller & Levine, 1982; Sweller, Mawer, & Howe, 1982, Sweller, Mawer & Ward, 1983) began investigating how learners learn schemas and patterns that facilitate problem solving, through conventional, practice-oriented instruction. These studies focus on methods of increasing novices' awareness of problem structure through practice (Owen & Sweller, 1985; Sweller et al., 1983). The theme of the time to become an expert was, "The best way to teach children how to solve problems is to give them lots of problems to solve" (Van Engen, 1959, p 74). After studying chess experts, Chase and Simon (1973) concluded, "Practice is the major independent variable in the acquisition of skill" (p 279).

Sweller's research programs soon accumulated empirical evidence showing that traditional, practice-based problem solving was less than an ideal method for improving problem-solving performance when compared to instruction that paired practice problem with worked examples (Cooper & Sweller, 1987; Sweller & Cooper, 1985). Laboratory protocol studies revealed that when presented with traditional practice exercises, learners tended to employ typical novice strategies, such as trail and error, while learners presented with worked examples before solving often employed more efficient problem-solving strategies and appeared to focus on structural aspects of problems.

A number of researchers, including Sweller and his colleagues, investigated the efficacy of using more worked examples in classroom instruction. Zhu and Simon (1987) conducted the first most widely cited of these studies. Studies by Carroll (1994), Ward, and Sweller (1990) also provided evidence in favor of the worked example instruction in the classroom rather than strictly problem-solving practice. In there most recent work Kalyuga and Sweller, (2004), presented novice students with diagrams and text in a format that separated the two sources of information learned less than novice students given materials that integrated the texts into the diagrams. The researchers posit that physical integration "reduced the need for mental integration and reduced extraneous cognitive load" (p 163). Further, the researchers found that as levels of expertise increased, the difference between the separate and integrated conditions first disappeared and eventually reversed with the separate condition superior to the integrated condition. Rather than integrating the diagrams and text, eliminating the text facilitated the best result. Interestingly, the text had become redundant for these more expert learners.

Worked examples

Multiple sources of information are often directed at learners who find one or more of the sources unintelligible and can only achieve understanding by mentally integrating the various sources of information into working memory. A *worked example* consisting of graphic and associated statements is an example. The purpose of a worked example is to display information by either text and or graphic for sequentially completing a task. Chandler and Sweller (1991) suggest that a worked example with a presentation format that integrates text and graphic information should reduce cognitive load. The activity of searching for text and graphic references in a diagram is likely to be cognitively demanding. Once the relevant information is found, the text and graphic must be mentally integrated. Attention must be devoted to both sources of information simultaneously. Both sources must be processed in order to effect the necessary mental integration.

The MWE

The MWE with the integrated format should facilitate learning in which the text and graphic both need to be processed to achieve understanding. When instructional developers do not consider working memory, transfer, and retention may suffer. The act of mental integration is cognitively demanding and is required because the traditional manner in which worked examples have been presented in the past have not taken into account working memory. MWEs are worked examples that are designed with text and graphics integrated, see appendix A.

The CWE

CWEs are worked examples with text and graphics separated, see appendix B. Comparing the MWE with the CWE, you will notice that the MWE has the text next to the graphic whereas the CWE the text is on one side of the instruction sheet and the graphic on the other. When corresponding words and graphics are far from each other, learners have to use cognitive resources to visually search for information from the corresponding text and graphics.

Split-attention effect

According to Sweller, separating the text and graphics the learner is subject to the split-attention effect (1998, 2004). The split-attention effect is defined as any impairment in leaning occurs when the learner must mentally integrate disparate sources of information. In the context of learning, Sweller and his colleagues have demonstrated the split-attention effect from worked examples (Chandler & Sweller, 1990; Cooper & Sweller, 1987; Sweller & Cooper, 1985; Ward & Sweller, 1990). When learners use a worked example, they must split their attention between the text and graphic and mentally integrate them into working memory before the information can be useful to them. The split-attention effect has been shown to be a major problem with some instructional designs (Chandler & Sweller, 1991, 1992; Kalyuga & Sweller, 2004; Sweller & Chandler, 1994; Sweller et al., 1990; Tarmizi & Sweller, 1988; Mousavi et al., 1995).

The learner who is using a worked example would then have to split their attention between the text and the graphic, which would increase cognitive load because of the additional elements of information.

Variation of worked example

How the text and graphics are designed and developed can have substantial effects on the learner's ability to assimilate that information. When learners use

MWEs, integrating text and graphics, performance is improved compared to CWEs where text and graphics are in two disparate locations. When worked examples are designed poorly, the learner must engage in irrelevant or ineffective cognitive processing; when the worked example is well designed, cognitive load is minimized (Mayer 2001).

Comparison of examples

Worked examples are used in other areas of curriculum, for example in industry requiring procedural testing on equipment. Figure 4 is a Conventional Worked Example, CWE that demonstrates an insulation-resistance testing procedure with text and graphic separate. Figure 5 is the same insulation resistance test procedure but it has been modified with the text and graphic physically integrated on the worked example. This modified worked example or MWE with the text and graphic integrated should reduce the split-attention effect and reduce cognitive load.

Comparing the CWE Figure 4, with the MWE Figure 5, there are two different worked examples for the same procedure. In Figure 2 the developer of this worked example elected to place the text at the top and the graphic at the bottom. The CWE requires the learner to first read the text then look at the graphic to explain visually the test procedure. The learner who only reads the instruction may not be able to perform the test because of the lack of clarity of the text or the complexity of the procedure. The learner may have to search for additional information on the worked example, which would increase the cognitive load. After reviewing the graphic, the learner may have to read the text several times before the text and graphic are integrated.

Figure 4 provides the learner with all the information on the worked example rather than in a separate section. When the learner views the graphic in Figure 4 and finds they are unable to solve the problem with the graphic presented, the learner will search for additional information. If the learner looks at the graphic prior to reading the text, the learner may not be able to perform the test because the graphic makes no sense until the text have been integrated, the learner must use additional cognitive resources to engage in the process of integration before proceeding with the test.

In Figure 5, the MWE presents the graphic and text together eliminating the split-attention effect. There is no need for the learner to search for additional information because the information has been integrated physically and no additional information is required for understanding.

Figure 4. Split-attention conventional worked example[4]

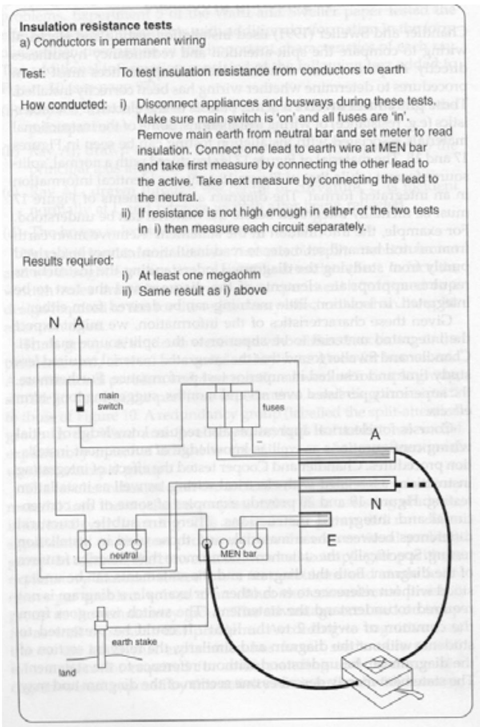
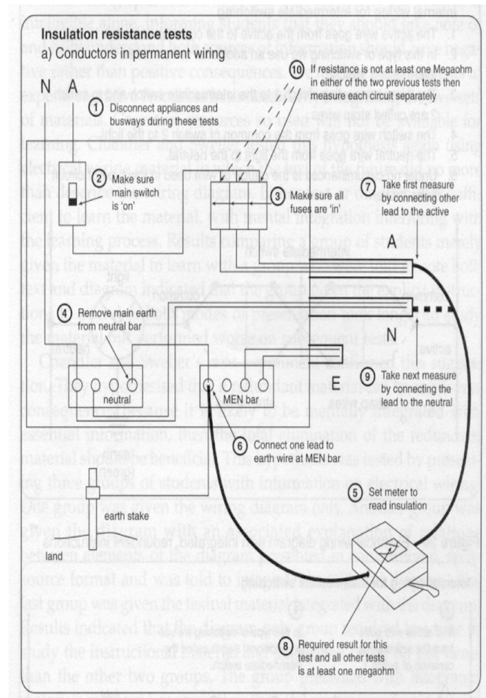


Figure 5. Integrate modified worked example[5]



History

In the past, the literature has presented no theoretical reasons for choosing a MWE over a CWE. Worked examples were developed randomly with respect to working memory. In traditional manufacturing environments, electrical or process engineers develop the worked examples. Their primary goal of the developer was

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[4]From "Instructional Design in Technical Areas" by J. Sweller, *Experimental evidence using electrical engineering processes*, p.120. Copyright 1999 by The Australian Council for Educational Research Ltd. Reprinted with permission of the author.
[5] From "Instructional Design in Technical Areas" by J. Sweller, *Experimental evidence using electrical engineering processes*, p.121. Copyright 1999 by The Australian Council for Educational Research Ltd. Reprinted with permission of the author.

to develop a worked example as quickly as possible without regard to the split-attention effect or cognitive load.

Not all curriculum area seems to have developed standard formats for worked examples because the various worked example structures were devised before knowledge of cognitive factors became available. They were quite inadequate in some areas for example, the algebra problem, but ideal in others like the geometry problem. Thus, on the evidence available currently, the normal format used to present algebra worked examples required no alterations. Neither theoretical grounds nor empirical evidence showed that students found the algebra worked example in its traditional format difficult to process. In contrast, the design of conventional geometry worked examples is quite inadequate. Both theory and data suggest that students in the geometry group found the CWEs difficult to process as compared to the MWE.

Cognitive load theory

Cognitive load theory is concerned with how cognitive resources are distributed during learning and problem solving. Many learning and problem-solving activities impose a heavy, extraneous cognitive load that interferes with the primary goal of the task. An extraneous cognitive load is defined as any cognitive activity that is engaged in because of the way the task is organized and presented to attain relevant goals. Some worked examples can impose a substantial cognitive load before learning commences. The presentation format of the worked example may require considerable initial mental reorganization and processing of elements.

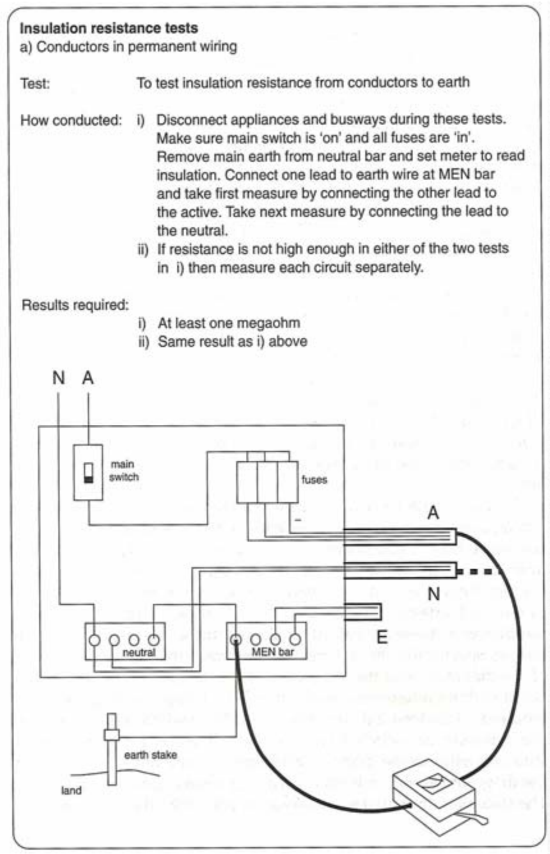
Split attention and redundancy

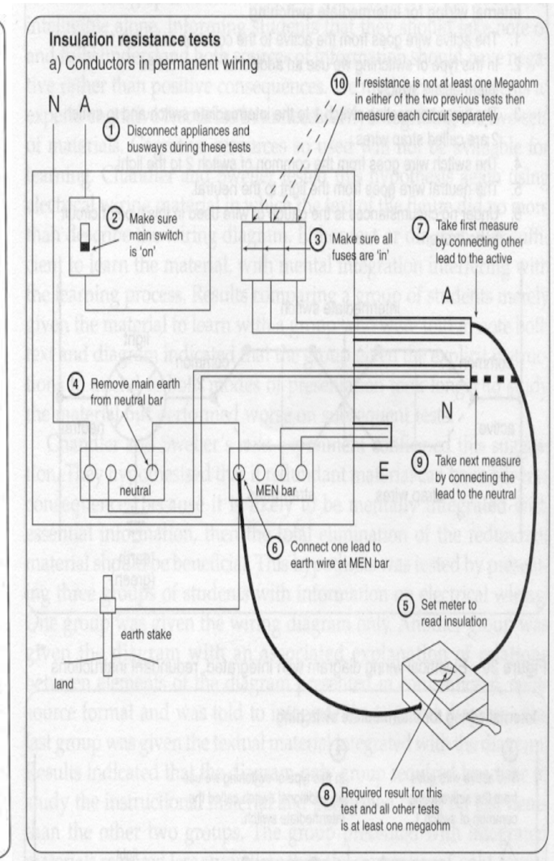
Chandler and Sweller (1991) demonstrated the effects of the MWE and CWE by comparing the split-attention and redundancy factors. The split-attention and redundancy effects are closely related. If two or more sources of information that refer to each other cannot be understood in isolation then the split-attention effect may arise. If they can be understood in isolation then the redundancy effect may arise. A source of information can be anything to which the learner must attend. In the CWEs, the activity of searching for textural references in a graphic is likely to be cognitively demanding due to the learner splitting their attention from text to the graphic. Once the relevant section is found, the text and graphic must be mentally integrated. Not only does attention need to be devoted to both sources of information simultaneously, but also both sources must be processed in order to effect the necessary mental integration.

The problems associated with the split-attention presentation format for geometry worked examples, were rectified by physically integrating the various sources of information. Under some conditions, physical integration may not be feasible. For example, in extreme cases, practical considerations may interfere, such as the excessive amount of integrated material that must be fitted on a small page.

Chandler and Sweller (1991) demonstrate how the CWE of Figure 4 can be reformatted to eliminate the need for learners to integrate several sources of information. In Figure 5, the written material, instead of being separated from the graphics, is incorporated into them. The need to search for appropriate referents in the text or graphic is eliminated because all corresponding text and graphics are closely coordinated. Because there is physical integration in the initial presentation, there is no need for learners to expend cognitive resources in mentally integrating the text and graphics. The cognitive load associated with the integrated materials should be less than that of the conventional instructions.

Figure 6. Split-attention CWE[6] Figure 7. Integrated MWE[7]





The materials used to demonstrate the split-attention effect in the insulation-resistance test example had one feature in common: the units of information had to be integrated before they could be understood. For example, it was necessary to integrate text and graphic, either physically or mentally, before either could be

[6]From "Instructional Design in Technical Areas" by J. Sweller, *Experimental evidence using electrical engineering processes*, p.120. Copyright 1999 by The Australian Council for Educational Research Ltd. Reprinted with permission of the author.

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understood. The units were not self-contained and intelligible if processed alone. There were cognitive load consequences because there was a necessity to integrate disparate sources of information.

Not all mutually referring sources of information necessarily must be integrated. Redundant information (see Figure 8) provides the clearest example of a situation where mental integration is voluntary. Viewing the information in Figure 8, readers can see that the graphic represents the circulation of blood in the human body.

Associated text describes important aspects of the graphic. The arrows indicate the direction of blood flow from the lower and upper body flowing into the right atrium. The graphic, being understandable without any reference to the text, renders the text redundant.

Reader's looking at the two sources of information presented in Figure 8 and comparing it with Figure 9, can see the sources of information are quite different between the multiple sources of information used.

Figure 8. Flow of blood in the heart, lungs and body, conventional worked example[8]

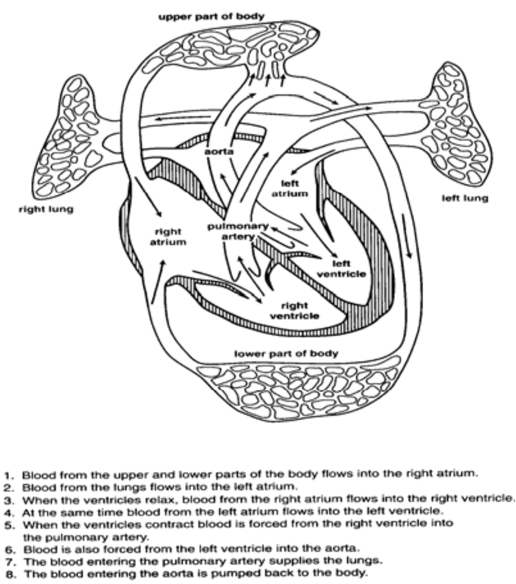
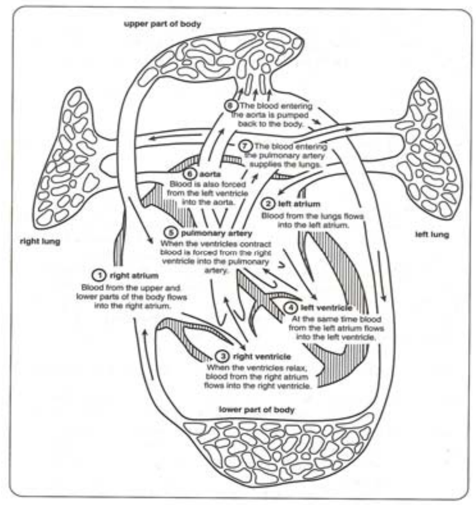


Figure 9. Flow of blood in the heart, lungs and body, modified worked example[9]



If a learner studies Figure 9 and realizes that the text is redundant and that all necessary information is contained in the graphic then his or her cognitive load should be reduced. If the learner chooses to study both the text and the graphic and mentally integrate them, then his or her cognitive load should be increased. Mental integration should have the same consequences with respect to cognitive

[8] From “Instructional Design in Technical Areas” by J. Sweller, *Experimental evidence using electrical engineering processes*, p.54. Copyright 1999 by The Australian Council for Educational Research Ltd. Reprinted with permission of the author.

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resources whether or not it is necessary. The cognitive load could be either light or heavy depending on the processing strategy that a learner chooses to use.

Instructions that include material that contains redundant information permit physical integration just as easily as instructions for which integration is necessary for understanding.

If that material is physically integrated, it will be difficult for learners to ignore the redundant information. Thus, physically integrated material should impose a heavier cognitive load than non-integrated materials under conditions where learners tend to ignore the redundant material. There is little opportunity to ignore the redundant material when it is integrated. In effect, learners are forced to process material that they do not need and, normally, would not process.

The split-attention and redundancy effects are closely related. If two or more sources of information that refer to each other cannot be understood in isolation then the split-attention effect may arise. If multiple sources of the same information can be understood in isolation then the redundancy effect may arise. Whether the multiple sources of information are intelligible in isolation will depend not just on the nature of the material but also on the experience of the learners. Information that is intelligible in isolation for one person may be unintelligible to another.

Stereotyping

In technical areas, instructional formats tend to be stereotyped.

1. New material is presented.

2. One or two worked examples provided the use of the new material, and last students are given a relatively large number of exercises on which to practice.

Instruction and worked examples

Worked examples are one aspect of instruction. Normally, they need to be preceded by introductory explanatory material. The layouts to present technical materials usually are determined by some combination of visual elegance, tradition, and random factors. Cognitive factors tend not to be predominating largely because until recently, cognitive theory was insufficiently developed to provide guidance. Packaging of information, Ross (1984, 1987, 1989) has demonstrated how superficial aspects of a problem influence the solution process.

The use of multiple sources of mutually referring information in instructional materials is common. It is especially common in areas requiring graphic material. Text and graphics usually are clearly separated, and the student is required to refer to the graphic while reading the text and probably required to refer to the text while studying the graphic. It is unusual to see text and graphics integrated into a single entity. There are, of course, several reasons for the conventional layout in worked examples.

Fads and traditions

Fads. Fads are someone's idea and belief of the latest way of developing worked examples from layout to the use of colors, text, and graphics. Fads are also promoted through professional organizations such as International Society

Performance Improvement, ISPI. Presenters from different industries such as manufacturing training departments present their “new way” of developing work instructions to audiences made up of instructional designers and curriculum developers. The audience is usually enthusiastic about the information presented but there never seems to be a follow-through to validate their findings on the learner’s performance from the development and use of the “new” work instructions.

Traditions. Traditions are the default in organizations that do not have a methodology of developing worked examples. The developer may not be an instructional designer and may not have had training in the development of developing worked examples. They may find it takes less time and more efficient for them to use the same layout that has been used in the past then to research the methodology on how learners’ process information. Fads come and go and traditions stay on but the problem with both approaches is that they do not take into account how learners process information with respect to the split-attention effect and cognitive overload.

Instructional Design

There was a considerable amount of research in the mid-1970s dedicated to identifying ways to facilitate concept learning by a growing number of cognitively oriented educational researchers began to look beyond the goal of acquiring discrete concepts. Researchers turned their focus to more complex forms of knowledge and learning (Brewer & Nakamura, 1984). Topics of interest included studying how experts and novices used knowledge to interpret experience and solve problems in domains such as chess, algebra, physics, and geometry. Research indicated that experts typically focus on deeper structural aspects of problems, whereas surface features (Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1982; Silver, 1982) often mislead novices. Schemas were conceived to be complex memory structures possessed by experts that enabled them to recognize a problem as a member of a class (e.g., a type of physics problem) and retrieve and interpretation and procedure appropriate for that class. From these experiments, researchers began to create worked examples.

Worked examples are instructional devices that provide the learner with information that may reduce the time of learning and reduce the errors when used to assemble components as in manufacturing environment. Worked examples are also presented to learners in all technical areas. It is suggested that the structure of those worked examples is frequently deficient and should be altered. Appropriately designed worked examples resulted in superior performance in learning and problem solving compared to conventional structured examples.

From worked examples, working memory is required in order to remember the problem being solved or learned. A common conception of those memories is the *schema*, which is a cognitive representation of a construct (an idea, concept, process, or phenomenon, for example). A schema for a problem consists of the kind of problem it is, the structural elements of the problem (such as acceleration, distance, and velocity in physics problem), situations in which such problems occur (included planes and automobiles, for example), and the processing operations required to solve that problem (Jonassen, 2003). When schemas are well organized and integrated, they can be brought into working memory as a whole, thereby placing lower demands on working memory. The development of problem schemas can be supported explicit modeling the structure of the problem during the worked example (Jonassen, 2003) and by practicing solving particular kinds of problems. With extensive practice and reflection, schemas form different kinds of problems become automated.

Cognitive and educational psychologists adopted the learning-by-example paradigm to examine and describe the processes involved in concept formation (Bourne, Goldstein, & Link, 1964; Bruner, Goodnow, & Austin, 1956; Tennyson, Wooley, & Merrill, 1972). While the examples used by these researchers were dissimilar to worked examples, they shared the same fundamental purpose: to illustrate a principle or pattern. From the perspective of educational psychologists, these studies could inform educational practice, particularly by showing how examples should be selected, presented, and sequenced (Tennyson & Cocchiarella, 1986). This focus on presentation and sequencing of examples paralleled the empirical investigations such as Bruner's (1996) *Toward a Theory of Instruction* and Glaser's (1976) *Components of a Psychology of Instruction: Toward a Science of Design*.

The major step in analyzing a worked example for effectiveness was determined by its requirements to the learner in mentally integrating mutually referring, disparate sources of information. This type of structure imposes an extraneous cognitive load that will interfere with the assimilation of the material. Mutually referring sources of information occur most obviously when we are dealing with diagrams and some other types of information such as text, statements of theorems, or equations. The cognitive load imposed by this process is likely to interfere with the learning and so the worked example may be inadequate. Cognitive resources must be used to reformulate the example prior to learning.

Worked examples that include diagrams are not the only origin of an extraneous cognitive load brought about by students having mentally to integrate extraneous sources of information. Any example that includes a detailed problem statement and question associated with the solution of that problem will usually require students to split their attention between the statement and the solution in order to understand the example. Arithmetic or algebra word problems provide the most obvious examples. When algebra is presented as worked examples they are formatted with separate problem statements and solutions. The problem statement will indicate that while it normally is intelligible in isolation, it does not constitute a worked example. The solution normally is not even intelligible without the problem statement. The worked example cannot be understood until after the statement and solution have been mentally integrated. Once integration has occurred, learning can begin. All worked examples will incorporate some mutually referring, disparate sources of information.

The use of worked examples to facilitate learning and problem solving in algebra led to the use of worked examples in other areas of academia. It was assumed that worked examples appropriately directed attention and reduced cognitive load irrespective of the subject matter. Worked examples eliminate the need for a means-ends strategy and this should eliminate the heavy extraneous cognitive load associated with the strategy for all subject areas.

From pilot studies and years later, it was clear theses assumptions were wrong, at least with respect to geometry and physics. There was no sign of the significant effects that were found when using algebra worked examples. If anything, the worked examples seemed to have marginally worse results than conventional problems. Now, these worked examples are seen as requiring inappropriate attention and heavy cognitive load.

Summary

A review of the literature demonstrates that some forms of worked examples have been ineffective because learners must split their attention between multiple sources of information e.g., text and graphics. There have been several studies using worked examples in courses as algebra, geometry, biology, and electrical wiring insulation testing but no studies have been conducted in a manufacturing environment using assemblers as subjects. This study differs from previous studies because it was conducted on-site at a manufacturing company using their assemblers' as subjects.

To date no study has been conducted on the use of worked examples in a manufacturing environment using assemblers as subjects. There is no data to confirm or contradict if either conventional or modified worked example would be a benefit in training assemblers. The use of the conventional worked examples without comparing them to modified worked examples is valueless for improvement of modified worked examples. No data exists that demonstrates that using conventional worked examples is superior in performance, reduction in assembly time and a reduction in errors in the finish product, when compared to the use of modified worked examples.

There are instructional design models that present sets of procedures intended to lead to the selection of the best possible instructional methods (Gagne & Briggs, 1979; Dick & Carey, 1985; Kemp, 1986). Instructional designers acknowledge that their design models do not always allow learners the most efficient design for the development of worked examples. This study provides instructional designers with techniques and methods for the development of worked examples. This study also includes suggestions for the design of modified worked examples for the reduction of the split-attention effect and for the reduction of cognitive load.

While sufficient research exists concerning cognitive characteristics and split-attention research must be conducted to enable our understanding how the learner’s experience level relates to the design of worked examples. By understanding multiple references with worked examples, instructional designers can determine whether the presentations given to learners should be in a multiple reference format. Worked examples research has been conducted in controlled laboratory settings using textbook problems from mathematics and science. There may be implications of these controlled experimental studies that may not include the naturalistic settings such as a manufacturing environment. The physical and cultural contexts shape our working personnel development and often are not taking into consideration and are controlled out of the experiment or not reported. However, there is strong evidence (Bruer, 1993; Kalyuga & Sweller; Renkl & Atkinson, 2003; McGilly, 1998) that controlled experimental research grounded in cognitive science has substantially improved educational practice.

CHAPTER III

METHODOLOGY

Introduction

This chapter describes the quasi-experimental design employed in the study. Following statement of the hypotheses, the two treatments and the variables are defined; the nature, selection, and assignment of the participants are detailed; and the instruments and materials are described. Then the next sections after these describes the procedures carried out during the pilot study, which was conducted to determine whether there were areas in which there was a lack of clarity in either the verbal or the written instructions for both groups, whether the scorecards used to rate the participants' success and speed were suitable to their function, and whether the researcher and observer were able to use them reliably. The chapter concludes with a brief description of the type of data analysis employed and a statement of compliance with the university's human subject procedures.

Research Questions

The hypotheses tested in this study were the following:

Hypothesis H_{O1}*:* Is there a difference in assembly time between the MWE and CWE groups?

Hypothesis H_{O2}*:* Is there a difference in the errors between the MWE and CWE groups?

Hypothesis H_{O3}: Is there difference in tasks completed between the MWE and CWE groups?

Variables

The independent variable in this study was the instructional treatment. One group of participants followed a set of MWEs, the other a set of CWEs. The assembly described in both sets of worked examples was identical; only the integration of text and graphics, in the case of the MWEs, and the non-integration of text and graphics, in the case of the CWEs, differentiated them. The three dependent variables were speed of assembly, incidence of errors, and number of completed steps of the assembly.

The first dependent variable was speed of assembly. The speed of the assembly was how long it took the participant to complete the individual assembly. The range of time for the individual tasks was from 0 to a maximum of 30 minutes. The researcher and one observer for each participant measured the time during each session. The researcher and observer would time each participant from the start of the tasks until either participant had completed the task or until 30 minutes were up. If the participant took longer than 30 minutes the researcher would say stop at which point the participant would stop what they were doing. Thirty minutes was the maximum time each participant had to complete the tasks.

The second dependent variable was incidence of errors. The range of errors ranged from 0, no errors, to 34 errors where each step was done incorrectly.

The researcher or the observer on a scorecard scored each error for each of the 34 steps.

The third dependent variable was the number of completed steps of the assembly. The number of completed steps ranged from 0 to 34. The researcher or observer would mark on the scorecard for each participant the number of completed steps then tally, after the experiment, the score for each completed step to determine the total of completed steps for that participant.

Participants and Selection

The participants in this study were 54 manufacturing assemblers employed by a manufacturing company in Fremont, California, that produced, in the division in which these employees worked, high intensity light bulbs used *inter alia* in film projection and in NASA's space shuttle. The selection of participants was accomplished with the assistance of the company's Human Resources (HR) division, which circulated a call for volunteers. Fifty-four employees in the department involved in assembly responded. The manager of the department accepted responsibility for arranging suitable times for the testing sessions. Of the 54 volunteers, 10 were selected for participation in the pilot study, the other 44 in the actual experiment.

At the beginning of each testing session, the volunteers were asked to complete a demographic questionnaire (Appendix D; and see below). The responses indicated that the ethnic breakdown of the 44 members of the main testing group was 3 percent African American, 41 percent Asian, 29 percent

Hispanic, and 29 percent White. The participants ranged in age from 20 to 65 years. As regards educational background, 2 percent had had zero to three years of formal education, 12 percent three to six years, 50 percent seven to twelve years, 30 percent thirteen to sixteen years, and 7 percent sixteen years or more. There were 22 males and 22 females in the sample. Table 1 summarizes the demographic data.

Table 1. *Demographic Data*

		Percentage
Time in Manufacturing		
	1-2 years	7.30%
	2-3 years	7.30%
	3 + years	85.40%
Time in Company		
	1-2 years	4.70%
	2-3 years	11.60%
	3+ years	81.40%
Ethnicity		
	Latino/Hispanic	28.60%
	Asian/Pacific Islander	40.50%
	African American	2.40%
	White	28.60%
Gender		
	Male	52.50%
	Female	47.50%
Education Level		
	0-3 years	2.30%
	3-6 years	11.40%
	7-12 years	50.00%
	13-16 years	29.50%
	16+ years	6.80%

The reading and interpretation of the MWEs or CWEs were not considered to pose any significant problem because the participants were currently using assembly instructions and engineering drawings closely resembling those in the CWEs.

Human Subjects Consideration

Approval from the University of San Francisco's Internal Review Board for the Protection of Human Subjects (IRBPHS) was obtained prior to conducting this study. All considerations were given to confidentiality and to ethical and moral issues for each participant. In accordance with the guidelines of the IRBPHS and the company's Rules and Regulations, participants were informed of their rights as participants both during the solicitation process and at the beginning of the instructional phase. The appropriate consent form (Appendix G) was given to each participant, and each was required to sign and return the form to the researcher prior to participation. All participants were assured that all personal information, both data from the demographic survey and results of the testing, would be held in strict confidence and would in no circumstances be communicated to their employer.

Materials

The researcher purchased two identical erector sets made by a French company. These kits, while relatively inexpensive, consisted of components that replicated quite closely those the subjects assembled at their daily workstations.

From the variety of different assemblies the kits were designed to build, the researcher selected a crane base assembly as the most suitable because of the complexity of the assembly and the moderate sizes of the parts used. The assembly required thirty-four steps.

Instruments

The researcher developed two sets of seven worked examples. Each set of seven sheets together contained 34 discrete steps making up the full assembly process chosen for the experiment. The first set, the MWEs, was developed with text and graphics integrated (see Appendix A) and the second set, the CWEs, was developed with text and graphics separated (see Appendix B).

Each of the seven MWEs and each of the seven CWEs was presented on a single 8.5" x 11" sheet of paper, printed landscape. Across the top of each sheet was printed the product number, product description, and other identifying data. Each MWE and each CWE then contained, in the left-hand column of each sheet, an inventory of the parts required, consisting of item numbers, part numbers, descriptions, and quantities; at the head of the left column, above the inventory, each CWE set out brief instructions for that phase of the process. In the right-hand column of each sheet was a graphic. In the CWEs the only text accompanying the graphic was a set of labels identifying each of the part numbers (Appendix B). In the MWE the assembly instructions and the identification of the parts by number and name were closely integrated with the graphics (Appendix A).

Procedures

Pilot Study

Before the actual experiment began, a pilot study was carried out. The purpose of the pilot study was to identify areas that might lack clarity in the verbal instructions for either the MWEs or the CWEs, to test the ease of use of the scorecard layout, and to ensure that the scoring of the steps of the process could be achieved reliably. From the volunteer list of 54 participants, 10 assemblers were assigned by the manager to participate in the pilot study. Because the workspace was a small classroom that was limited in size, it was decided that all participants in both the pilot study and the main experiment would be tested in groups of two, one using a MWE and the other a CWE.

The manager assigned the first two participants to report to a designated classroom at a set time and continued to assign pairs of participants until all 10 had been tested. When each pair of participants arrived, the researcher invited them to sit at one of two positions, at either end of an 8-foot table. No attempt was made to influence their choice of position. The participant who chose to sit on the right-hand end of the table would receive a set of MWEs and the participant who sat on the left-hand end would receive a set of CWEs. The participants did not know what kind of instructions they would receive when they entered the room. Apart from the researcher and the two scheduled participants, one observer was present for every session.

On the table in front of each participant was a set of part containers with all necessary components of the crane base, with each compartment labeled with the part category number it contained, corresponding with the part numbers shown on the working example sheets. Neither participant was able to see what the other was doing because each participant was sitting at each end of an eight-foot table and the part containers obstructed each of the participant's view of the other's work. Each participant could only see his or her assembly and part containers.

Before seeing their sets of worked examples, subjects signed the consent form, completed the demographic survey, and then listened to the verbal instructions presented by the researcher, consisting of an explanation common to both sets of worked examples, MWEs and CWEs. During this phase, and this phase alone, participants were permitted to ask questions of the researcher.

At this stage during each two-person session, the researcher gave each participant either a set of seven MWEs, those with text and graphics integrated, or a set of seven CWEs, those with non-integrated text and graphics, but at this time they were face-down on the table. The participants were asked first to count their worked example sheets to make sure each had received a full set of seven worked examples. The researcher then reviewed the elements of both the MWEs and the CWEs. The researcher read each item aloud, then the subjects were asked to respond to questions elicited from the researcher and from this process it was determined they understood the English Language. To assist in their understanding of the printed directions, the participants were shown two sample items, one MWE and one CWE, by overhead projection. The researcher made every effort in each session to ensure that both subjects had responded and had indicated their understanding of the procedures before continuing. (See Appendix E for the script.)

At this point, the participants were asked to turn their worked example sheets face-up and to begin. At this point the timer was started. The researcher gave no assistance or feedback in any way during the testing period. After 30 minutes, they were asked to stop what they were doing, whether finished or not.

During the pilot study, the researcher and observer used the scorecard to score each of the 34 steps. A video camera, to provide a check on the scoring, was positioned to capture the movements of each participant. After each two-person session, the participants were thanked for their contribution. The ten participants who had taken part in the pilot study were not used in the main study. The scoring is explained below.

The scorecards, listing by number each of the 34 steps entailed in selecting and placing the various parts in correct sequence, enabled the researcher and observer to record every detail of the process as it occurred. As a participant completed each step, the researcher or the observer recorded a score for that step: a step completed correctly was scored “1” and a step completed incorrectly was scored “0.” (For a non-attempted or incomplete step, the corresponding space was left blank.) In each two-person session each workstation was labeled with a number (1–10) identifying the subject taking the test there. This number was videotaped together with the subject's movements, subsequently the researcher used the tape to validate the researcher's, and observer's scoring. In total, the experiment ran approximately 35 minutes from start to finish for each pair of subjects tested.

Each completed scorecard was compared, systematically, with the videotape of the assembly for accuracy. There were no indications that the participants in the pilot study had difficulty following the instructions, so it was concluded that these, too, were clear. The time for the experiment was not an issue because all the participants' in the pilot study had completed the seven set of MWEs or CWEs within the time limit of 30 minutes. No changes were considered necessary to the procedures, scorecards, or instructions because of the pilot study. Further, the particular worked examples used in the study had been used by the researcher in the past as a training exercise in another industry. They had worked satisfactorily in that setting, and now appeared to have been equally satisfactory in this pilot study. Therefore it was determined that these materials would be suitable, without change, for the regular study.

Main Study

The participants in the main study were each assigned a number in the range 1–44. For the same reason as applied in the pilot study, participants were tested in pairs, each pair assigned by the manager at a designated time. The set-up in the testing room was identical to that employed for the pilot study and the procedures—from completion of the consent form and demographic questionnaire through the introduction, the use of overhead projection to show parallel worked examples, and the dialog between researcher and participants to ensure understanding, to the 30-minute test itself—were likewise identical.

While the participants worked, the researcher and observer, one per participant, manually scored each session (see Appendix C) as described above in the Pilot Study section. The researcher and observer, one for the subject with the MWE, the other for the subject with the CWE, had a scorecard (Appendix C) and scored each of the 34 steps (a step being the actual movement the assembler made either to select or to place each part).

Validity and Reliability

The design of this study employed the standard method by which assemblers are instructed in the manufacturing environment. They may be instructed in a classroom or self-taught at their workstations. In the classroom, setting the instructor sets the pace of instruction and the leaner must keep up. In contrast, the employee at their workstation can control the rate of learning at which they progress by reviewing the worked example at their own pace. Both methods of training require a worked example, or a set of worked examples, to instruct workers in the assembly of the product. Because the worked example is the standard way of delivering instruction in manufacturing, the worked examples used in this study were considered to have high content validity. Because of the high content validity and the high degree of scoring reliability, no changes or modifications were made to the worked examples.

The researcher and observer who took part in this study tested the reliability of the instrument during the pilot study, in which 10 volunteers participated in successive pairs. The researcher observed one participant while the observer observed the other participant, while the process was videotaped simultaneously. The researcher and observer subsequently checked their scorecards for accuracy against the videotape. For each participant, there were 34 scores for the 34 steps on each scorecard, which totaled 340 possible scores for the 10 participants. After reviewing the videotape, both the researcher and the observer mutually agreed that of the 340 scores, 337 scores or 99 percent of the total were scored accurately. The degree of reliability in the use of the scorecard was therefore determined to be high.

Data Analysis

Descriptive statistics using means and frequencies were calculated for all of the relevant variables: assembly time, errors, and completed tasks. Two-tail t-tests were used to determine whether there were any statistically significant differences between treatment groups for each of the 3 dependent variables. The level of significance set for the t-test analyses was .05.

CHAPTER IV

RESULTS

Introduction

This study investigated whether a modified form of assembly instructions (MWEs) embodying the integration of text and graphics would increase assembly line efficiency by reducing assembly time, reducing errors, and increasing the number of completed tasks, when compared to the conventional form of instructions (CWEs) containing non-integrated text and graphics.

The hypotheses tested in this investigation were:

1. *Is there a difference in assembly time between the MWE and CWE groups?*
2. *Is there a difference in the number of errors between the MWE and CWE groups?*
3. *Is there a difference in tasks completed between the MWE and CWE groups?*

Hypothesis 1

Hypothesis 1 compared the difference between the 2 groups (n=22 for each group), to determine if there were differences in assembly time between the groups.

As shown in Table 2 below, the MWEs had a mean of 26.65 minutes with a standard deviation of 5.00, the CWEs mean was 26.21 with a standard deviation of 5.85. The t and p values were .268 and .862 respectively. Table 2 indicates there was no significant difference between the treatment groups in total time in assembly between the MWE and the CWE group at the .05 level.

Table 2 Difference in Total Time for Each Group

Instructional Treatment	n	Mean	Standard Deviation
MWEs	22	26.65	5.00
CWEs	22	26.21	5.85

Table 3. Frequency Distribution for the MWE and CWE Assembly Times

Worked Examples	Time in Minutes	Participants	Percentage
MWEs	16.3	1	4.5
	17.0	2	9.1
	18.0	1	4.5
	23.3	1	4.5
	25.3	1	4.5
	25.5	1	4.5
	27.0	1	4.5
	27.3	1	4.5
	29.7	1	4.5
	30.0	12	54.5
CWEs	11.4	1	4.5
	12.3	1	4.5
	16.3	1	4.5
	19.0	1	4.5
	26.0	3	13.6
	26.5	1	4.5
	27.0	1	4.5
	27.5	1	4.5
	28.5	1	4.5
	29.9	1	4.5
	30.0	10	45.5

Table 3 reveals 22 participants did not complete the tasks; 12 participants from the MWE group and 10 participants from the CWE group. In other words, the participants who completed all of the tasks did so between 11.4 and 29.9 minutes.

A second analysis was done to more accurately describe the outcome of the participants who completed the experiment within the allotted time. Table 4 below, gives the results of the analysis from participants who completed the experiment within the time allotted.Table 4.

Table 4. Total Time by Group that Completed All Tasks

Instructional Treatment	*n*	Mean	Standard Deviation
MWEs	10	28.31	2.03
CWEs	12	26.87	5.58

When the analysis was done on those participants who completed all the tasks within the time allotted, the mean for the MWE was 28.31 with a standard deviation of 2.03 and the CWE groups mean was, 26.87 with a standard deviation of 5.58 with a

t of -.730 and a p=.334. The difference in time to complete the tasks was not significant at the .05 level. Based on the results of these t-tests, there was no difference on job performance, in terms of time to complete all the tasks, between the two groups.

Hypothesis 2

Hypothesis 2 addressed the errors made between the 2 groups during the assembly of this product. A frequency table was generated showing the 34 steps matched with the correct (1) and error (0) values, and blank for uncompleted steps. In Table 4, it may be seen, in the MWE and CWE columns that 19 errors were made in the assembly process by the MWE group and 13 errors by the CWE group. That is, the assemblers using CWEs made 32 percent fewer errors than those using MWEs. It appears there was a higher level of accuracy on the part of assemblers using CWEs.

Table 5. Frequencies of Error, Correct, and Uncompleted for the MWE and CWE for Each Step

	MWE			CWE			
Step	Errors	Correct	Uncompleted	Errors	Correct	Uncompleted	Total
1	2	20			22		44
2	3	19		1	21		44
3		22			22		44
4		22		1	21		44
5	1	21		1	21		44
6	3	19		6	15	1	44
7	2	20			20	2	44
8	1	21			20	2	44
9	1	20	1	1	19	2	44
10	2	19	1		20	2	44
11	1	21		1	19	2	44
12	1	20	1		19	3	44
13		21	1		19	3	44
14	2	19	1		19	3	44
15		19	3		19	3	44
16		17	5		19	3	44
17		14	8		19	3	44
18		14	8		19	3	44
19		14	8		18	4	44
20		14	8		18	4	44
21		14	8		18	4	44
22		14	8		17	5	44
23		13	9		15	7	44
24		13	9		15	7	44
25		13	9		13	9	44
26		13	9		13	9	44
27		13	9		13	9	44
28		13	9		13	9	44
29		11	11		12	10	44
30		11	11		12	10	44
31		10	12		11	11	44
32		10	12	1	9	12	44
33		10	12		10	12	44
34		10	12	1	9	12	44
TOTAL	19	544	185	13	569	166	1496

Table 6 presents the mean for the MWE group at 2.32 with a standard deviation of 2.43 and the CWE group with a mean of 2.18 with a standard deviation of 2.32 with a *t* of -.967 and a *p*= .339. The results indicate that there was no effect of treatment on completed tasks as the results were not statistically significant at the .05 level.

Table 6. Means and Standard Deviations for Errors between the MWEs and CWEs

Instructional Treatment	*n*	Mean	Standard Deviation
MWE	22	2.32	2.43
CWE	22	2.18	2.32

Hypothesis 3

The third hypothesis looked at whether there would be an increase in completed assembly steps when MWEs were used. The mean for the MWE group was 25.86 steps and the standard deviation was 5.01. The CWE group had a mean of 24.72 steps with a standard deviation of 5.85. These values can be seen in Table 6, below. A two-tail *t*-test was used to assess whether there were statistically significant differences between these two groups, the *t*-value was .390 and *p*=.699. The results indicate there was no effect of treatment on completed tasks as the results were not statistically significant at the .05 level.

Table 7. Means and Standard Deviation for Assembly Steps Completed

Instructional Treatment	*n*	Mean	Standard Deviation
MWE	22	25.86	5.01
CWE	22	24.72	5.85

Ancillary Analysis

The purpose of the ancillary analysis was to look at additional data that may help to explain the results of this study and present data to identify variables for future studies.

In the ancillary analysis, the researcher examined two specific areas that relate to this study. Both areas came from the demographic survey: time in years the participant was working for the company where the study was conducted and the number of years the participant was working in manufacturing.

The Relative Experience of the Participants

Table 8 displays the length of time in years that the participants had worked for the company where the study was conducted. The data indicate that 80.0 percent had been working for the company for more than three years. This would suggest that a senior, more experienced workforce participated in this study. One person failed to complete the question regarding how many years they had worked for the company.

Table 8. Time in year’s participants had been working for the company

n	Time Working	Percentage
1	0–1	2.3
2	1–2	4.5
5	2–3	11.4
35	3+	79.5
1	missing	2.3
Total		100.0

Table 9 indicates the number of years the participants had been working in the manufacturing division for this company. From the data presented, 76 percent had 3 or more years in a manufacturing division. Three participants did not complete this demographic question on the questionnaire.

Table 9. Time in years participants had been working in the manufacturing division

n	Time Working	Percentage
1	0–1	2.4
3	1–2	7.3
3	2–3	7.3
34	3+	75.7
3	missing	7.3
Total		100.0

The results (shown in Tables 8 and 9), suggest that one of the reasons why the incidence of errors did not differ significantly between the MWE and CWE groups may have been that the participants were relatively experienced and had become accustomed to working with conventional work examples when learning new assembly tasks.

Summary

Three different dependent variables were tested in this study: assembly time, errors, and number of tasks completed and 2 independent variables, modified worked example and a conventional worked example. A total of 44 participants equally divided into 2 groups of 22 each, volunteered to participate. Modified worked examples, MWEs, were given to one-half of them and conventional worked examples, CWEs, to the remainder.

When testing all 3 hypotheses, there was no statistical significance between the groups. Therefore, our best conclusion is that there is no difference between the MWEs and CWEs for the particular dependent variables for this study.

An ancillary analysis was presented that indicated the high number of experienced participants, those with more than three years with the company, almost all of whom had worked for that time in manufacturing. This relative high level of previous experienced workers may have skewed the results. Experienced workers were presumably well accustomed to working with CWEs prior to this study. The company had been reducing labor force, the more experienced having the advantage over their less experienced co-workers, and it may not have been possible at the time of this study to use less experienced workers. The finding of the study is that, the use of MWEs is not more effective when compared with CWEs with assemblers in a manufacturing environment.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Introduction

The purpose of this study was to examine differences between two types of worked examples to assess which form of worked example was more effective in facilitating assembly workers' in their jobs. Current training models, employing conventional worked examples (CWE) cause learners to split their attention between text and graphics when learning a new process. Therefore, modified worked examples (MWE) were created to test whether reducing cognitive load in working memory could produce a more effective training tool. A procedure was created to assess which worked example was more effective in training manufacturing personnel. The factors compared consisted of assembly time, incidence of errors, and number of tasks completed. Although the original research plan called for 200 participants, it commenced with only 54 participants because of a reduction in force resulting from a downturn in the semiconductor-manufacturing sector.

Limitations

Sample Size

The first limitation of the study is that it was conducted in a manufacturing environment with a sample size of 54 participants, 44 of them for the main study. This small size may have affected the results in that it did not provide a large variety in demographics. Because of the small sample size, the statistical power of the study was limited.

Availability of Participants

The second limitation to this experiment was in relation to the selection of employees. The limitations with this were changes in the company, decrease in production and time restrictions. The first problem consisted in the global economic conditions that were taking place during the beginning of this study. It was first expected that there would be 200 employees made available from 3 different manufacturing plants. However, layoffs were taking place, causing subjects to be unavailable as well as scheduling the experiment to be delayed. By the time that the experiment could be conducted, only 54 participants were available.

Work Experience

The third limitation was in the high average level of experience of assemblers using CWEs. The sample size consisted almost entirely of assemblers thoroughly experienced in the use of CWEs. Therefore, instead of comparing average workers' use of a CWE with average workers' use of a superior worked example, MWE, this study ended up comparing experienced workers using a familiar worked example with experienced workers using an unfamiliar worked example. Because of the small sample size that was used, there were problems in acquiring a large enough sample size with less work experience. The time in which the participants in the study had been working with the company and working in manufacturing appeared to be unbalanced. Eighty percent of the participants had three years or more working for this company and 76 percent of the participants had three or more years working in manufacturing. This may have skewed the results and presented an unbalance assumption that the MWE would be superior in assembly time, reduced errors, and would have completed more assemblies within the allotted time. This may have given the participants' the ability to easily adjust to either of the worked examples than a less experienced assembler who might not done as well with assembly time, errors, and time to complete assemblies.

A third type of concern was the number of male and females in the actual study. A two-tail t-test was performed on male and females in the two groups, MWE and CWE. The MWE group had equal numbers of males and females, 11 males and 11 females. In this group the mean number of steps completed correctly by the males was 21.91 and the mean number completed correctly by females was 26.36. In the CWE group, with a slightly higher number of males than females, 12 and 10 respectively, the gender difference was comparable: the mean score for the males was 23.00 steps completed correctly and for the females 28.13 steps completed correctly. The females had the same overall error rate as the males, but they completed more steps correctly. In other words, the females made fewer errors per step. It appears that the females were better at following instructions than the males, and therefore completed more steps accurately than did the males.

Worked Examples

Another limitation was in the choice of worked examples to use. These worked examples first went through a pilot study with 10 participants. During the pilot study, the allotted time of 30 minutes appeared to be sufficient to complete the tasks before time elapsed. During the actual experiment, the time allotted was, again, 30 minutes but the results indicated that 50 percent of the participants, whether using MWEs or CWEs, did time out. This is interesting because the participants from the pilot study were from the same sample group as the participants from the actual study. Their manager assigned the participants for both the pilot study and the actual study in the exact same way. The manager assigned the first two participants to report to a designated classroom at a set time and continued to assign pairs of participants until all participants had been tested. It is not clear from the results why the participants in the pilot study completed the tasks within the time allotted and 50 percent of the participants in the actual study could not complete the task.

The researcher was unable to observe or to acquire the actual task performed or determine the time the assembler had to complete their task at their workstation. In future studies it is suggested the researcher try to obtain what the participants actual duties are, review their worked examples and try to determine the time they are allotted to complete their required tasks at their workstation. It was unfortunate that the researcher did not determine the task the assembler was assigned or the time the assembler had to complete the assembly because it may have provided clues that led to the pilot study participants completing the task within the 30-minute limit. In future studies, it is recommended that not only the time be increased but have the participants provide more information about their work environment and the type of work they do. By increasing the time of the study and providing a survey for additional information about their work environment, this research project may have had different results with time to assemble, errors, and time to complete the assembly.

Interpretation of Results

The three hypotheses addressed the efficiency of the assembly line when modified worked examples, as compared with conventional worked examples, were used in terms of reducing assembly time, reducing errors, and increasing the number of completed tasks. Both MWEs and CWEs contained both text and graphics, but in the former, they were integrated and in the latter, they were not.

Assembly Time

The first hypothesis addressed the time to assemble.

Hypothesis $H_{O1:}$ *Is there a difference in assembly time between the MWE and CWE groups?*

The data indicated the mean score for the MWEs was 26.65 minutes whereas the mean score for the CWEs was 26.21 minutes. This may suggest that comparing the MWE with the CWE in time to assemble, the MWE was 1.68 minutes longer than the CWEs time to assemble. However, this was not the case because the results of a two-tail t-test indicated at the .05 level of significance, there was no significant advantage when using an MWE compared to a CWE.

Error Rate

The second hypothesis addressed the incidence of errors during the assembly of this product.

Hypothesis $H_{O2:}$ *Is there a difference in the number of errors between the MWE and CWE groups?*

An error frequency table was generated for the 34 steps matched with the error and correct values and uncompleted. The data indicated that the MWE group made 19 errors in the assembly process and the CWE group made 13 errors. That is, the assemblers using MWEs made 46 percent more errors than those using CWEs. From the frequency table data, a two-tail t-test was performed on both the MWE and CWE to determine whether there was a significant difference in error rate between the MWE group and the CWE group. The results indicated at the .05 level of significance, there was no significant difference in the use of either the MWE or CWE for the reduction of errors.

Task Completion

The third hypothesis addressed the number of completed assembly steps when MWEs were used.

Hypothesis H_{O3}: Is there a difference in the number of tasks completed between the MWE and CWE groups.

The mean for the MWE group was 25.86 steps and for the CWE group 24.72 steps. A two-tail t-test was used to assess if there were statistical significance differences between the two groups. The result of the two-tail t-test was .390 and *p*=.699, which was not statistically significant.

Thus far in this section, it can be seen that comparing the MWE to the CWE, there was no statistical significance that would indicate that use of the MWEs was superior to that of the CWEs in time taken to assemble, incidence of errors, or number of steps completed.

Ancillary Analysis

The researcher performed an ancillary analysis using two demographic factors form the survey to ascertain whether there were other variables that might help explain the lack of statistically significant difference between the two types of worked example. The two factors used were the length of time participants had worked for the company and the length of time participant had been working in the manufacturing section in particular.

From the frequency table indicating the time in years participants had been working for the company, it emerged that 35, or 79.5 percent, of the participants had spent three or more years working for this company and only eight, below 20 percent, of the participants had served less than three years. The next demographic factor considered was the participants' level of experience—the number of years that participants had been working in the manufacturing section. The data were very similar: 34, or 75.7 percent, of the participants had worked three years or more manufacturing and only seven, again below 20 percent, had less than three years of experience. These two variables may have been responsible for skewing the results, reducing to zero any statistically significant difference between the two assembly instructional types. Further research, using a broader range of employees including in particular a more typical balance between expert and novice assemblers and those in between, might produce a more indicative result.

The study findings indicate that experienced assemblers using MWEs do not take significantly less time to assemble a product, do not make fewer errors, and do not complete more tasks. This finding does not support the use of MWEs for senior, more experienced assemblers, which confirms pervious research findings (Van Merrienboer & Sweller, 2005). The study provides a basis for further research within the manufacturing environment as it relates to the design and development of worked examples. However, this study is the first study using worked examples with assemblers in a manufacturing environment and point the way forward for future research in the area of worked examples.

There is considerable evidence in the literature of research on worked examples (Van Merrienboer, 1990; Van Merrienboer & Sweller, 2005), which compared to CWEs, MWEs decreased cognitive load, facilitated the construction of effective schemas, and led to better transfer of performance. In previous duration studies (Kalyuga et al., 2004); Van Merrienboer, 2003), results indicated that completion problems were equally effective as worked examples intermixed with conventional problems. In studies of longer duration, completion problems may better help learners maintain motivation and focus their attention on useful solution steps that are available in the partial examples (Ericsson & Kintsch, 1995; Sweller, 2003, 2004).

Chandler and Sweller (1990, 1991) and Sweller (1989) have pointed out that worked examples have to be structured effectively. According to these researchers, students should not be faced with activities that impose extraneous cognitive load, such as mentally integrating and mutually referring disparate sources of information (e.g., text and graphic). These researchers suggested that the instructional designer should integrate the multiple sources of their information in the worked examples. While the results of the present study did not confirm their expectation of improvement, the data consistent with the hypothesis that MWEs may be better for assembly where novices are concerned. One drawback of modified worked examples is that they can be time-consuming to construct. An instructional designer must consider which part of the solution is presented to the learners, or from the opposite perspective, which part is left for learners to complete for themselves. There are two issues in particular that the instructional designer should address. A good completion problem typically requires that the learners must first understand the partial solution before they are able to complete it and second must understand how to perform nontrivial completion. This presents the instructional designer with a considerable number of decisions.

Chi and colleagues (1982) pointed out that good students use worked examples in a way that are different from the way that poor students use them.

The researchers concluded from students’ self-explanations that students’ ability level determines the way students make use of worked examples. During problem solving, good students use the examples for specific reference, whereas poor students reread them to search for a solution. Furthermore, good students seem to refer to the examples less frequently within each solution attempt. In relation to the Chi et al. study, a similar argument can be made for the present study, namely, that senior workers are able to overcome bad instructional design, whereas novices may struggle more. One reason why seasoned workers do not do better with better designed instructions may be that they may be more resistant to change (Van Merrienboer et al., 2005). The assumption is that senior workers can overcome faulty instructions; arguably, and more importantly might be that they resist being asked to do things differently. Interestingly, the same may have been true for both genders; although, the women were better at following their worked examples, they were no better than the males comparatively speaking, at taking advantage of better-designed instruction.

Novices lack sophisticated schemas associated with a task or situation. For inexperienced learners, there is no instructional guidance for holding a given situation or task as provided by schemas in long-term memory. Instructional guidance can act as a substitute for missing schemas and can be effective as a means of constructing schemas. Effective instruction provides instructional guidance while minimizing working memory load (Sweller, 1999, 2004; Sweller et al., 1998). If the instructional presentation fails to provide necessary guidance, learners will have to resort to problem-solving search strategies that are cognitively inefficient because they impose a heavy working-memory load.

Experts, on the other hand, bring their activated schemas to the process of constructing mental representations of a situation or task. They may not need additional instructional guidance because their schemas provide full guidance. If the instruction provides information designed to assist learners in constructing appropriate mental representations, and experts are unable to avoid attending to this information, there will be an overlap between the schema-based and the redundant instruction-based components of guidance. For more experienced learners, instead of risking conflict between schemas and instruction-based guidance, it may be preferable to eliminate the instruction-based guidance. Consequently, instructional guidance, which may be essential for novices, may have negative consequences for more experienced learners. The situation in which an instruction design that includes guidance is beneficial for novices (resulting in better performance when compared with performance of novices who receive a format wherein such guidance is omitted) but disadvantageous for more expert learners (resulting in poorer performance when compared with performance of experts who receive a format wherein such guidance is omitted) is considered an expertise reversal effect.

Kalyuga, Chandler, and Sweller (2001) found that inexperienced electrical trainees benefited from textual explanations integrated into the diagrams of electrical circuits to reduce split attention. They were not able to comprehend a diagram-only format. However, more experienced trainees performed significantly better with the electrical circuit diagram-only format. More experienced trainees also reported less mental effort associated with studying the diagram-only format. For these experienced learners, the textual information, rather than being essential and so best integrated with the diagram, was redundant, and should be eliminated. The split-attention effect for novices was replaced by the redundancy effect for experts. An instruction design that included explanatory material in an integrated format was superior for novices but inferior for knowledgeable learners, which demonstrates an expertise reversal effect.

Using textual materials, Yeung, Jin, and Sweller (1998) also obtained this effect. Integrating explanatory notes into the primary text assisted learners with low levels of language competence. The same format, on the other hand, retarded leaning for more expert learners because the integrated notes, although redundant, were difficult to ignore when integrated into the primary text. The most important instructional implication of this effect is that, to be efficient, instructional design should be tailored to the level of experience of the learners who are receiving the instruction.

Theoretical Implications

Additional research is needed on the measurement of cognitive load. New methods must be devised to gauge a) cognitive load experienced by learners, b) the cognitive demands of instructional materials, and c) the cognitive resources available to individual learners. The information that learners must process varies in many dimensions, the extent to which relevant elements interact being a critical feature. Information varies from low to high in element interactivity. Each element of low-element interactivity material can be understood and learnt individually, without consideration of any other elements. The elements of high-element interactivity material can be learned individually, but they cannot be understood until all of the elements and their interactions are processed simultaneously. Consequently, high-element interactivity material is difficult to understand.

Future research with MWEs should be done on their impact on senior manufacturing assemblers in comparison to novice manufacturing assemblers. The sample employed in the present study, for reasons beyond the researcher's control, did not exhibit a broad range of experienced and non-experienced assemblers. Future studies might attempt to remedy this by requiring the demographic survey to be completed prior to assignment to the study. For future research the use of the responses from the demographic survey could enable the participants to be divided into two equal groups, each including assemblers representing as wide range of experience as possible. Similarly, the selection of each group should aim for a wider range of experience in actual manufacturing. To determine which type of worked example more effectively reduces cognitive load, thus, reducing assembly time and errors and increasing the number of tasks completed, future studies must review the demographics more closely to provide a more balanced sample of participants' experience.

Methodical Implications

Several recommendations are appropriate for future research to ensure better outcomes in similar studies conducted in work environments. The first recommendation is to obtain a more diverse range of subjects. While the company that was used was very helpful in finding participants, there were problems with getting the right types of participants. In future, it would be ideal to be able to have both a larger sample and a wider variety of subjects, both in terms of time with company and time in manufacturing. The experience level of the participants would have to be determined prior to the actual study. One proposal would be to have the participants complete the demographic survey prior to the pilot study, then assign one MWE group and one CWE group to include both levels of experience i.e., with the most experienced and with the least experienced in two individual groups. The participants would then be assigned by the number years they had in the manufacturing division of the company. This ought to provide a suitable variety of seniors and novices to find the best type of worked examples. A novice would be someone who had not worked for the company or who had been there for less than six months.

Practical Implications

This study was a beginning to allowing the instructional design practices in manufacturing to be revisited in terms of the development of worked examples. Through this and future studies to determine which type of worked examples work best, the systems that are now used to train workers and students may change to better serve both trainees and the instructional designers who are designing and developing worked examples for the manufacturing assembler.

Summary

Instructional design used for developing worked examples often cause problems. If the worked example is not designed to the level of experience of the assembler, the senior assembler may find the worked example to be distracting and not helpful being trained to learn a new process. In some cases, when instructional material is presented to more experienced learners, a part or all of the provided instructional material might be redundant. An instructional format without redundant material is likely to be the best instructional format for the more experienced learners because all the necessary support for the construction of mental representations in working memory is provided by schema-based knowledge structures held in long-term memory. In contrast, that same material may be essential for less experienced learners.

Worked examples often cause problems in the understanding and learning of these new tasks. Usually they are designed in a way that separates text and graphics. Worked examples that integrate text and graphics should reduce the number of sources of information for those being trained. If such improved ways of presenting information can be found, assemblers may be enabled to better assimilate new information in working memory, resulting in a decrease in assembly time, a reduction in errors, and an increase in productivity.

This study has the potential for instructional designers to open new doors in the development of worked examples. By using different types of worker experience in future studies, new kinds of worked examples may be devised for use in more effective training of more productive workers.

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APPENDIX A

Modified Worked Examples

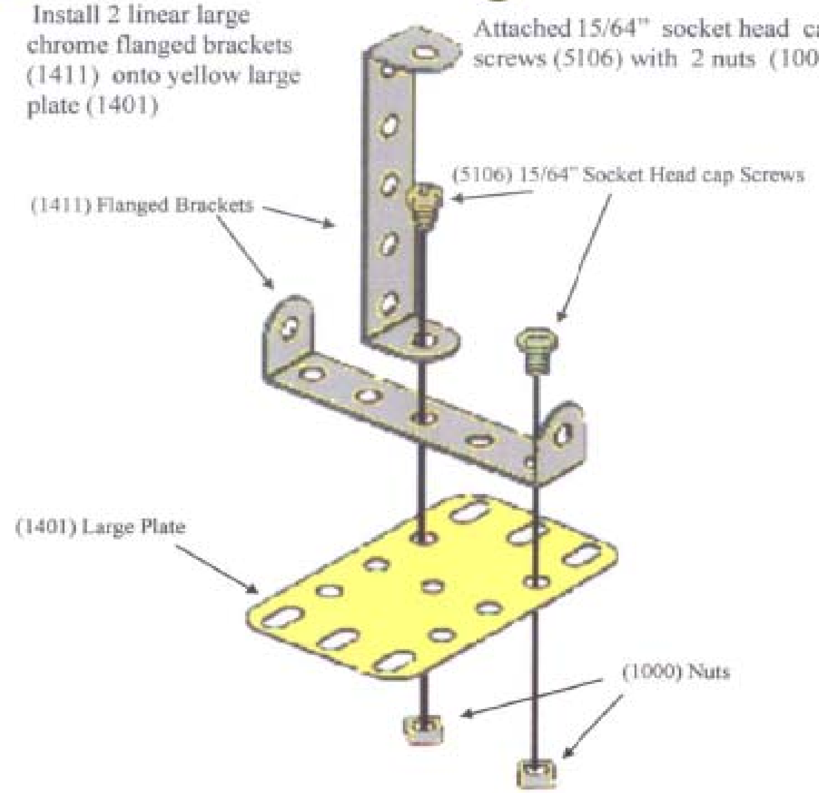
Operation Method Sheet

Product Number: 0001-2002	Product Description: BASE	Process Identification: Moving Crane	Operation #: 1	S.O.E. Range: From: To:	Revision Level 03/ 15 /02

Item	Part Number	Description	Qty
1.	1411	Bracket, Flanged Linear Large Yellow	2
2.	1401	Plate, Large Yellow	1
3.	5106	Screw, 15/64 Socket Head Cap	2
4.	1000	Nut	2
5.	1411	Bracket, Flanged Linear Large Yellow	1

1. Install 2 linear large chrome flanged brackets (1411) onto yellow large plate (1401)

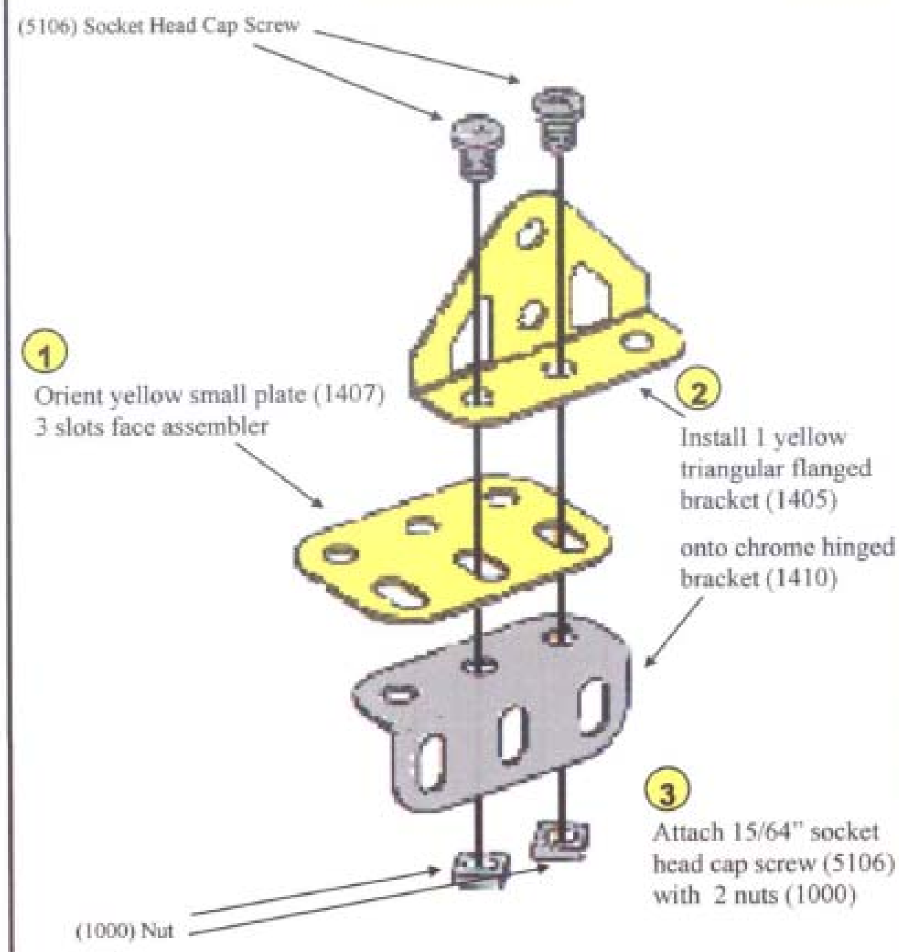
2. Attached 15/64" socket head cap screws (5106) with 2 nuts (1000)



Operation Method Sheet

Product Number:	Product Description:	Process Identification:	Operation #:	S.O.E. Range:	Revision Level
0001-2002	BASE	Moving Crane	2	From: To:	03/ 15 /02

Item	Part Number	Description	Qty
1	1405	Bracket, Flanged Triangular Yellow	1
2	1407	Plate, Small Yellow	1
3	1410	Bracket, Hinged	1
4	5106	Screw Socket Head Cap	2
5	1000	Nut	2



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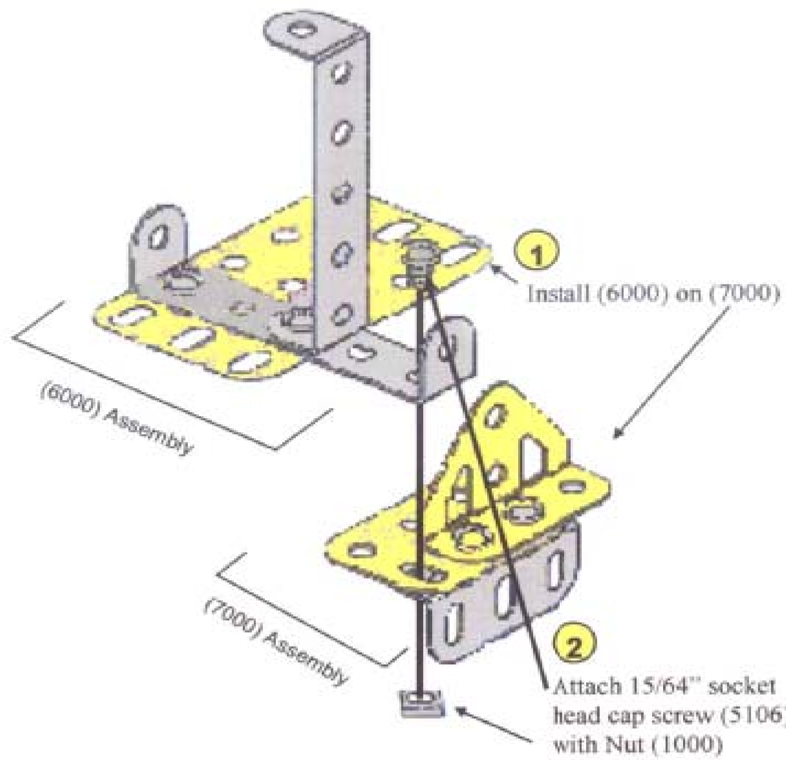
Operation Method Sheet

Product Number: 0001-2002	Product Description: BASE	Process Identification: Moving Crane	Operation #: 3	S.O.E. Range: From: To:	Revision Level 03/ 15 /02

Item	Part Number	Description	Qty
1	6000	Assembly	Ref
2	7000	Assembly	Ref
3	5106	Screw 15/64 Socket Head Cap	1
4	1000	Nut	1



Operation Method Sheet

Product Number:	Product Description:	Process Identification:	Operation #:	S.O.E. Range:	Revision Level
0001-2002	BASE	Moving Crane	4	From: To:	03 /15 /02

Item	Part Number	Description	Qty
1	8000	Assembly	Ref
2	5105	Screw 29/32 Socket Head Cap	1
3	900	Spacer, Large	1
4	1418	Insert, Yellow, Round	1
5	2000	Capsin, Rubber	1
6	1000	Nut	1

1

Slide parts onto:

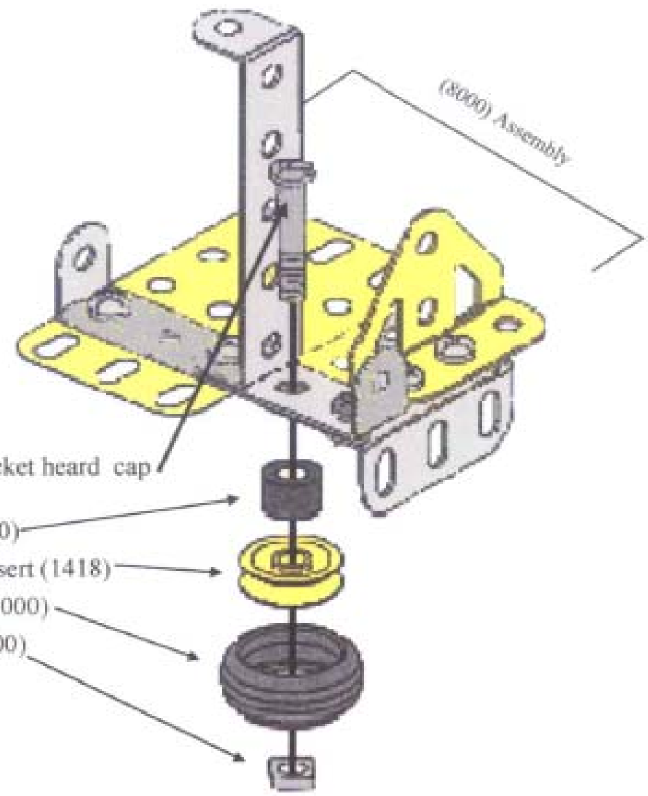
-- 29/32" onto socket heard cap screw (5105)

--large spacer (900)

--round yellow insert (1418)

--rubber capsin (2000)

----attach nut (1000)



4 of 7

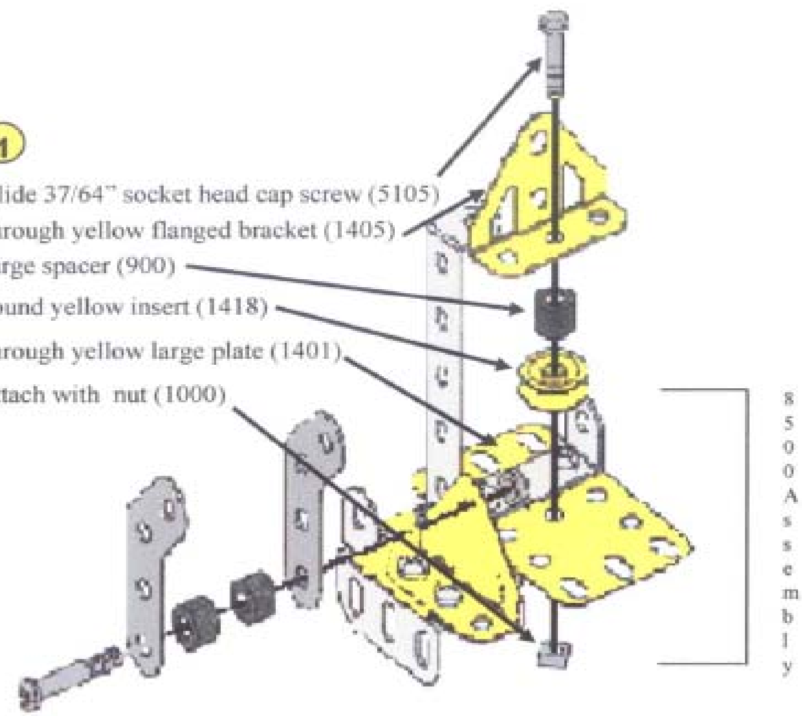
Operation Method Sheet

Product Number:	Product Description:	Process Identification:	Operation #:	S.O.E. Range:	Revision Level
0001-2002	BASE	Moving Crane	5	From: To:	03/15/02

Item	Part Number	Description	Qty
1	8500	Assembly	Ref
2	5105	Screw 37/64 Socket Head Cap	1
3	1401	Yellow Large Plate	
4	1405	Bracket, Flanged, Triangular, Yellow	1
5	900	Spacer, Large	1
6	1418	Insert, Yellow, Round	1
7	1000	Nut	1

1

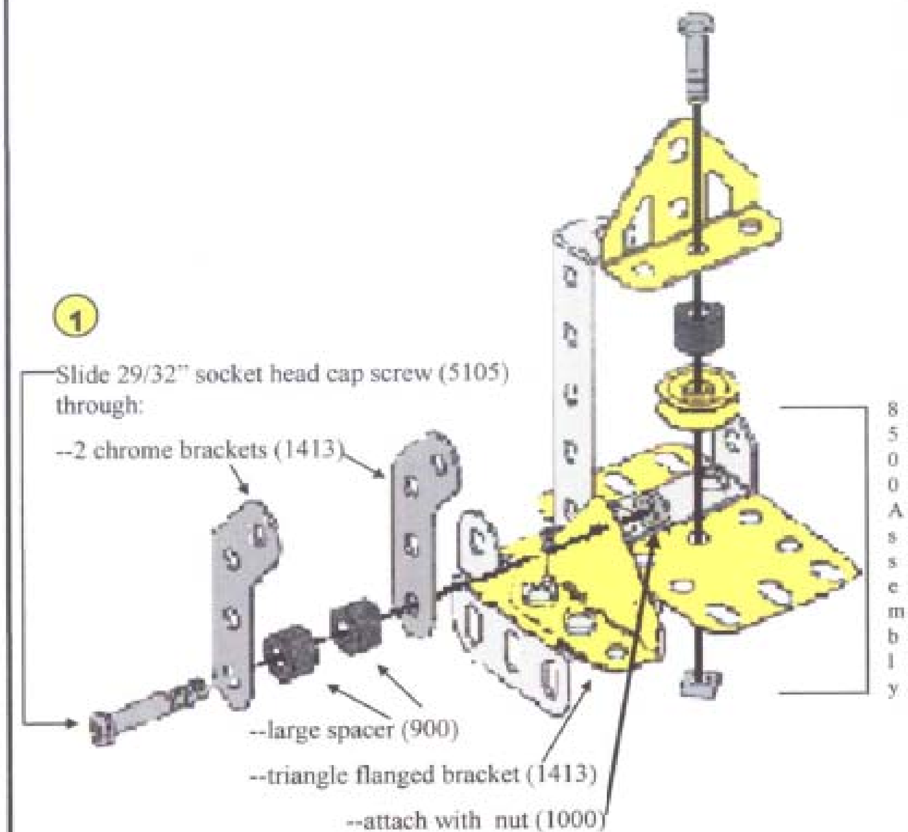
Slide 37/64" socket head cap screw (5105)
through yellow flanged bracket (1405)
large spacer (900)
round yellow insert (1418)
through yellow large plate (1401)
attach with nut (1000)



Operation Method Sheet

Product Number: 0001-2002	Product Description: BASE	Process Identification: Moving Crane	Operation #: 6	S.O.E. Range: From: To:	Revision Level 03/15/02

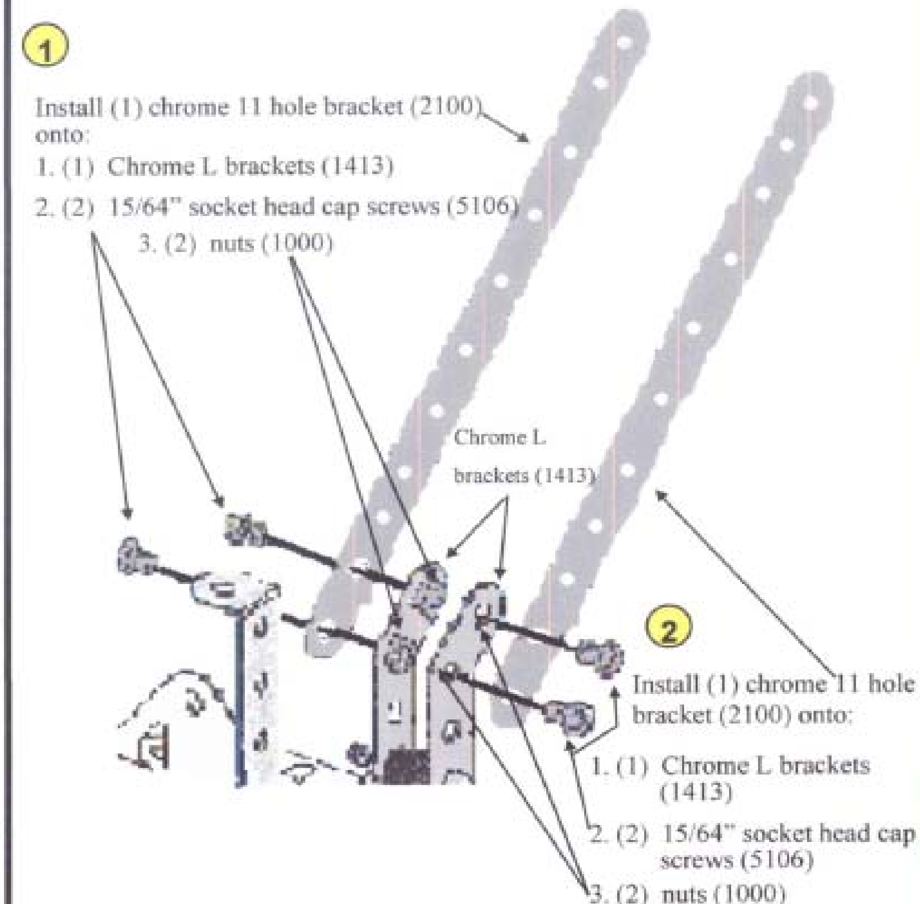
Item	Part Number	Description	Qty
1	8500	Assembly	REF
2	5105	Screw, 29/32 Socket Head Cap	1
3	1413	Bracket, Large, Chrome	2
4	900	Spacer, Large	2
5	1405	Triangle Flanged Bracket	1
6	1000	Nut	1



Operation Method Sheet

Product Number: M-0001-2002	Product Description: BASE	Process Identification: Moving Crane	Operation #: 7	S.O.E. Range: From: To:	Revision Level 03/15/02

Item	Part Number	Description	Qty
1	2100	Bracket 11 hole	2
2	5106	Screw 15/64 Socket Head Cap	4
3	1413	Chrome Brackets	2
4	1000	Nut	4



APPENDIX B

Conventional Worked Examples

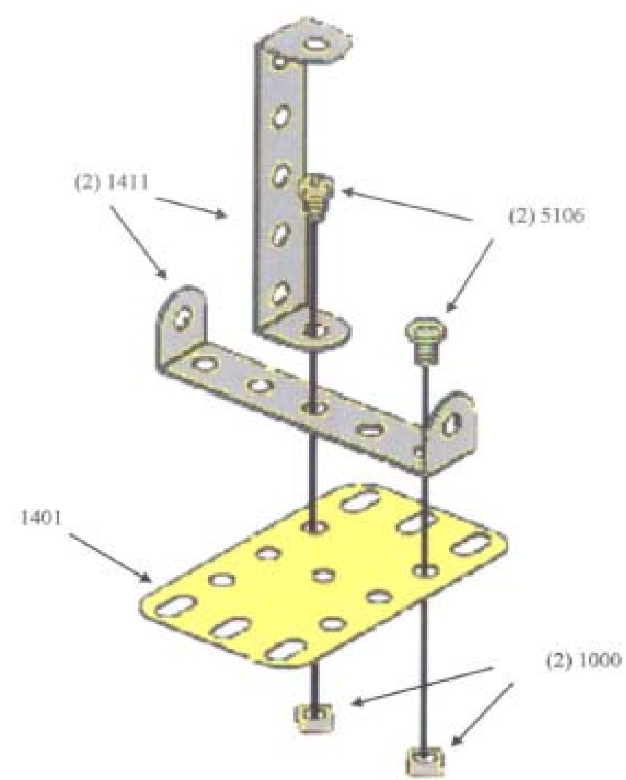
Operation Method Sheet

Product Number:	Product Description:	Process Identification:	Operation #:	S.O.E. Range:	Revision Level
0001-2002	BASE	Moving Crane	1	From: To:	03/ 15 /02

Instructions

Install 2 linear large chrome flanged brackets (1411) onto yellow large plate (1401) with socket head cap screws (5106) and 2 nuts (1000).

Item	Part Number	Description	Qty
1.	1411	Bracket, Flanged Linear Large Yellow	2
2.	1401	Plate, Large Yellow	1
3.	5106	Screw, 15/64 Socket Head Cap	2
4.	1000	Nut	2
5.	1411	Bracket, Flanged Linear Large Yellow	1



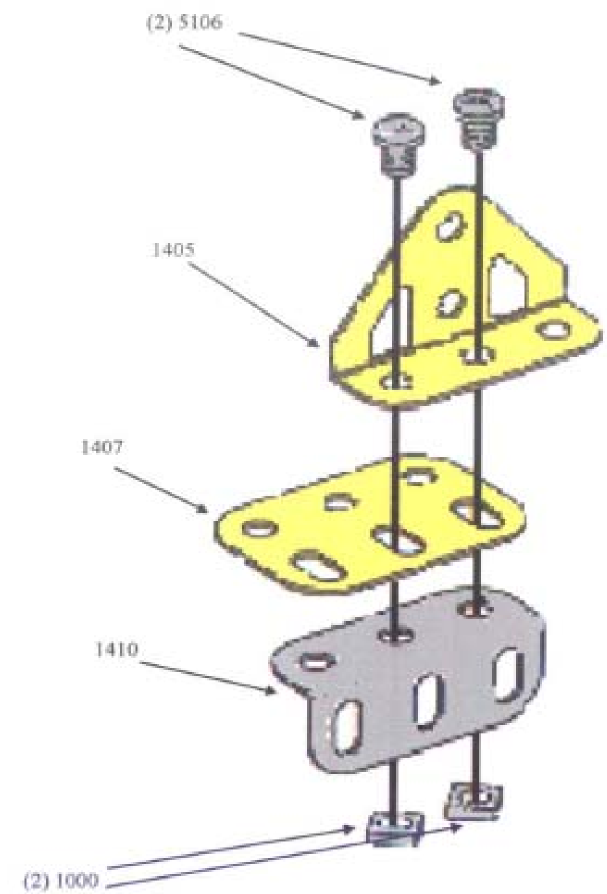
Operation Method Sheet

Product Number:	Product Description:	Process Identification:	Operation #:	S.O.E. Range:	Revision Level
0001-2002	BASE	Moving Crane	2	From: To:	03/ 15 /02

Instructions

1. Orient yellow small plate (1407) 3 slots face assembler
2. Install 1 yellow triangular flanged bracket (1405) onto chrome hinged bracket (1410) with yellow small plate and 2 15/64" socket head cap screw (5106) and 2 nuts (1000)

Item	Part Number	Description	Qty
1	1405	Bracket, Flanged Triangular Yellow	1
2	1407	Plate, Small Yellow	1
3	1410	Bracket, Hinged	1
4	5106	Screw Socket Head Cap	2
5	1000	Nut	2



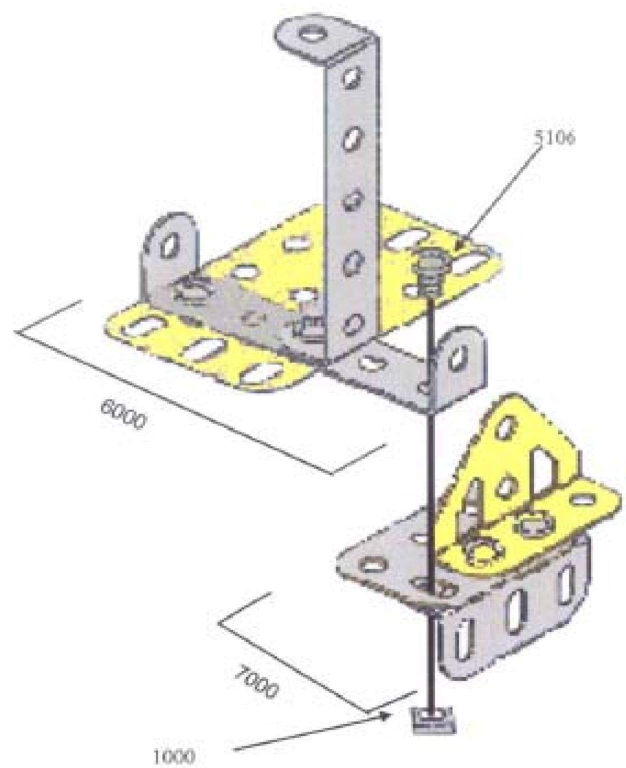
Operation Method Sheet

Product Number:	Product Description:	Process Identification:	Operation #:	S.O.E. Range:	Revision Level
0001-2002	BASE	Moving Crane	3	From: To:	03/ 15 /02

Instructions

Install (6000) on (7000) with socket head cap screw (5106) Nut (1000)

Item	Part Number	Description	Qty
1	6000	Assembly	Ref
2	7000	Assembly	Ref
3	5106	Screw 15/64 Socket Head Cap	1
4	1000	Nut	1



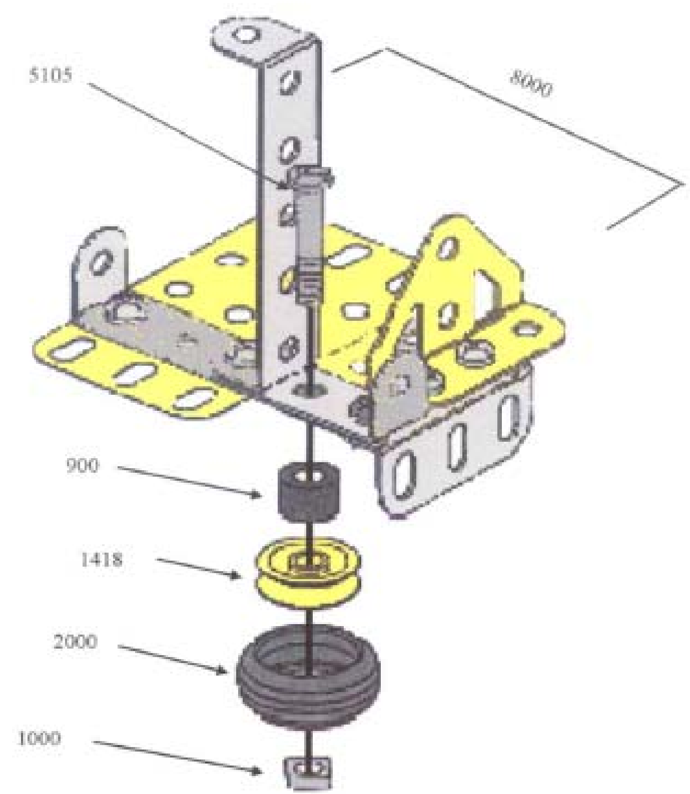
Operation Method Sheet

Product Number:	Product Description:	Process Identification:	Operation #:	S.O.E. Range:	Revision Level
0001-2002	BASE	Moving Crane	4	From: To:	03 /15 /02

Instructions

Install assembly (6000) on assembly (7000) with socket head cap screw (5106). Slide parts: large spacer (900), round yellow insert (1418), rubber capsin (2000) and 29/32' onto socket heard cap screw (5105) then attach nut (1000).

Item	Part Number	Description	Qty
1	8000	Assembly	Ref
2	5105	Screw 29/32 Socket Head Cap	1
3	900	Spacer, Large	1
4	1418	Insert, Yellow, Round	1
5	2000	Capsin, Rubber	1
6	1000	Nut	1



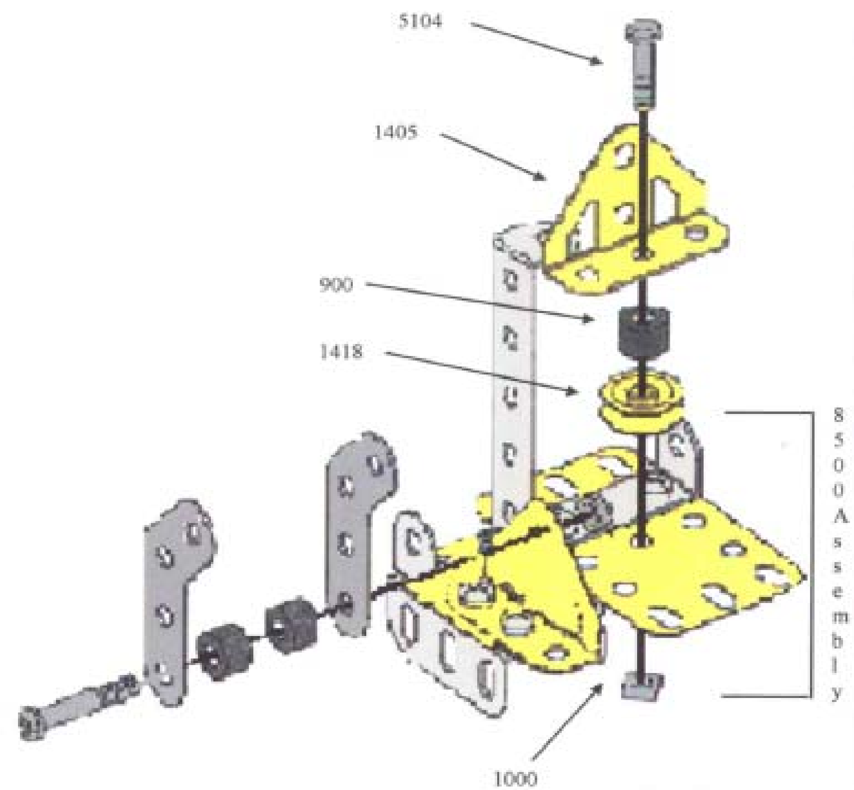
Operation Method Sheet

Product Number:	Product Description:	Process Identification:	Operation #:	S.O.E. Range:	Revision Level
0001-2002	BASE	Moving Crane	5	From: To:	03/ 15 / 02

Instructions

Install yellow flanged bracket (1405) onto yellow large plate(1401), large spacer (900), round yellow insert (1418), with 37/64" socket head cap screw (5104), and nut (1000).

Item	Part Number	Description	Qty
1	8500	Assembly	Ref
2	5104	Screw 37/64 Socket Head Cap	1
3	1405	Bracket, Flanged, Triangular, Yellow	1
4	900	Spacer, Large	1
5	1418	Insert, Yellow, Round	1
6	1000	Nut	1



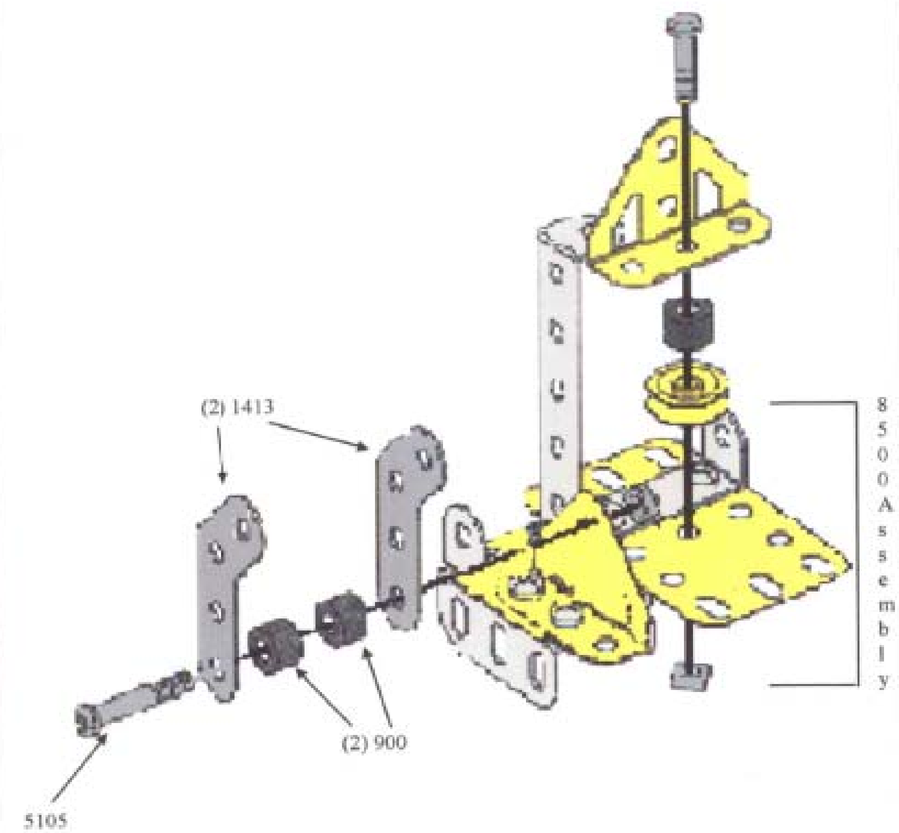
Operation Method Sheet

Product Number: 0001-2002	Product Description: BASE	Process Identification: Moving Crane	Operation #: 6	S.O.E. Range: From: To:	Revision Level 03/15/02

Instructions

Install 2 chrome brackets (1413) with large spacer (900) onto yellow triangle flanged bracket on yellow small plate with 29/32" socket head cap screw (5105) and nut (1000).

Item	Part Number	Description	Qty
1	8500	Assembly	REF
2	5105	Screw, 29/32 Socket Head Cap	1
3	1413	Bracket, Large, Chrome	2
4	900	Spacer, Large	2
5	1000	Nut	1



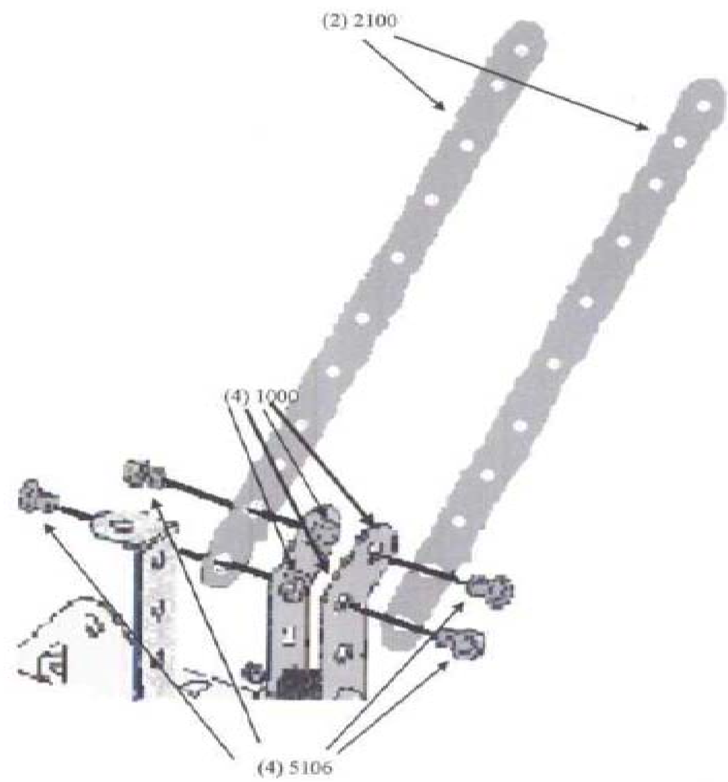
Operation Method Sheet

Product Number:	Product Description:	Process Identification:	Operation #:	S.O.E. Range:	Revision Level
0001-2002	BASE	Moving Crane	7	From: To:	03/15/02

Instructions

Install (2) chrome 11 **hole** bracket (2100) onto **chrome** L brackets (1413) with 4 15/64" socket head cap screws (5106) and 4 nuts (1000)

Item	Part Number	Description	Qty
1	2100	Bracket 11 hole	2
2	5106	Screw 15/64 Socket Head Cap	4
3	1000	Nut	4



APPENDIX C

Scorecard

Date:
Start Time:________Finished Time:______

Scorecard for
Modified & Conventional Worked Examples

Seq. #	Task	Score	Comments
	Worked Example 1		
1.	Install 2 linear large chrome flanged brackets 1411 onto yellow large 1401		
2.	with 2 15/64” socket head cap screws		
3.	5106 plate		
4.	Attach 2 nuts 1000		
	Worked Example 2		
5.	Orient yellow small plate 1407 slots face assembler		
6.	Install 1 yellow triangular flanged bracket 1405 onto chrome hinged bracket 1410 with small plate		
7.	Install 2 15/64” socket head cap screw 5106		
8.	Attach 2 nuts 1000		
	Worked Example 3		
9.	Install assembly 6000 on assembly 7000		
10.	Insert 15/64” 5106		
11.	Attach 2 nuts 1000		
	Worked Example 4		
12.	Select socket head screw 5105		
13.	Slide Parts: large spacer 900		
14.	Round yellow insert 1418		
15.	Rubber capsin 2000		
16.	Attach nut 1000		

Date:
Start Time:________Finished Time:_______

Scorecard for
Modified & Conventional Worked Examples

Seq. #	**Task**	**Score**	**Comments**
	Worked Example 5		
17.	Insert yellow flanged bracket 1405 onto yellow large plate 1401		
18.	Select socket head cap screw 5104		
19.	Slide through yellow plate 1401		
20.	Large spacer 900		
21.	Round yellow insert 1418		
22.	Attach with nut 1000		
	Worked Example 6		
23.	Select socket head cap screw 5105		
24.	Slide through: 1 chrome bracket 1413		
25.	2 large spacer 900		
26.	1 chrome bracket 1413		
27.	Through center top hole of triangular flange		
28.	Attach with nut 1000		
	Worked Example 7		
29.	Install 1 chrome 11 hole bracket 2100 onto 1 chrome L bracket 1413		
30.	Insert 2 15/64” socket head cap screw 5106		
31.	Attach with 2 nuts 1000		
32.	Install 1 chrome 11 hole bracket 2100 onto 1 chrome L bracket 1413		
33.	Insert 2 15/64” socket head cap screw 5106		
34	Attach with 2 nuts 1000		

APPENDIX D

Demographic Survey

Respondent Demographic Survey

In the following questions place a check mark next to the answer that most fits your response.

1. How long have you been working in manufacturing as an assembler?

   a. Less than 1 year___ b. 1-2 years___ c. 2-3 years___ d. More than 3 years___

2. How long have you been **working for** this company?

   a. Less than 1 year___ b. 1-2 years___ c. 2-3 years___ d. More than 3 years___

3. How many years of training have you had **in manufacturing**?

   a. Less than 6 months___ b. 6-12 months___ c. 1-2 years___ d. More than 2 years___

4. In addition to English, what other language(s) do you speak?

   a. Spanish___ b. Tagalog___ c. Mandarin or Cantonese___ d. French___

   e. Vietnamese___ f. Japanese___ g. Other_____ h. None___

5. What is your racial or ethnic background?

   a. Latino/Hispanic___ b. Asian/Pacific Islander___ c. African American/Black___

   d. Euro American/White___ e. Other___ f. Multi-Racial___

6. How old are you? _______

7. Were you born in the United States? Yes_____ No____

8. Indicate your gender: Male___Female___

9. How many years of schooling have you had? Less than 3 years____ 3-6 years____

   7-12 years____ 13-16 years____ more than 16 years____

APPENDIX E

Instruction Script

Instructional Script

The following is the script that will be used during the pilot and the test phase for this study.

Good morning and thank you for participating in my study on worked examples. My name is James Dill and my assistant name is _______________. I am a doctoral student at the University of San Francisco in the Learning and Instruction department in the school of Education. I have developed this experiment using worked examples similar to the ones you use at your workstation. The purpose of my study is to compare the conventional worked example with the modified worked example that I developed. The experiment will take you approximately 30 minutes from start to finish.

Before I begin the instruction phase of this study, I would like you to fill out the consent form that is in front of you. This form will inform you about the study and will authorize me to use you as a subject. Please take a few minutes and read the consent form and sign it. If you feel you cannot participate for any reasons please tell me now and you may leave.

Are there any questions?

Thank you for signing the consent form. The next item I would like you to fill out is the demographic survey. The information on this survey will be used to correlate items that you filled out. Please take a moment and fill out the survey.

Thank you for signing the consent form and filling out the survey. We well now proceed to the instruction phase of this study.

Overhead project will be on with a slide of either the modified or conventional worked example. Please look at the screen at the modified or conventional worked example. Please note when you use the worked examples to assemble the product the worked example will be very close to the one I am showing you now. The only difference will be the format but the information I am about to give you now will be the same. I will hand out your worked examples after I complete the instructions.

Looking at the overhead on the screen. When you look at your worked example you will notice the following. First, the worked example you have (modified or conventional) written is at the top. The line below will have the product number, product description, process identification, operation number, S.O.E. Range, and a Revision Level.

For the modified group the following will be explained. On the left side of your worked example you will notice a list of materials that include item number, part number, description, and quantity. On the right side, notice is a graphic with a circled yellow number starting with one. Below that number is a description in text that you are to follow. Next to each part there are arrows from the part name with the part number in parentheses. At the bottom of the worked example, a number tells you what page you are on and with the total number of pages. The first page will look like this, 1 of 1 and the final page will look like this, 7 of 7. There are a total of 7 worked examples.

The assembly has 7worked examples and they need to be done in the sequence from the first page 1, through page 7.

For the conventional group the following will be explained. On the left side of your worked example you will notice instructions for the assembly and underneath the instructions is a list of materials that include item number, part number, description, and quantity. On the right side notice a graphic and part numbers and arrows pointing to the part. At the bottom of the worked example, a number tells you what page you are on and the total number of pages. At the bottom of the worked example, a number tells you what page you are on and the total number of pages. The first page will look like this, 1 of 1 and the final page will look like this, 7 of 7. There are totaled of 7 worked examples.

The assembly has 7 worked examples and they need to be done in the sequence from the first page 1, through page 7.

Are there any questions?

For either group modified or conventional I will ask 3 questions. Pointing to the screen, I will ask both of the subjects the following questions. First, where on the worked example do you find the instructions? Second, where do you find the part numbers for each part? Third, where do you look to find which page I am on?

After the subjects have answered the 3 questions correctly the following instruction will be stated.

Pointing to the containers on the workstation. Notice at your workstation you have several containers with parts in them. Also notice the label on the container has the part number that is inside that container.

Are there any questions?

Passing out the worked examples. Here are your worked examples. Take a moment and make sure you have 7 (modified or conventional) worked examples.

Are there any questions?

You may now begin. When you are finished leave you assembly on the workstation and return to your work.

Thank you again for your participation.

APPENDIX F

Consent Form

Participants' Statement of Consent

I agree to participate in a research project being conducted by James Dill in conjunction with the University of San Francisco's Learning & Instructional doctoral program. I understand that the intent of this study is to contribute to professional knowledge in the manufacturing environment using worked examples. I have been informed that the purpose of the research study is to compare modified and conventional worked examples as it pertains to assemble line production in a manufacturing environment.

I understand that my participation in this study is entirely voluntary. If I wish to withdraw my consent later, I may freely do so without even after I sign this consent form. I agree that I will notify James Dill if I choose to withdraw my consent to participate in this study.

I understand there is no physical risk or discomfort involved, and I am protected from any potential embarrassment by the safeguard described in the Privacy Protection section of this form. I understand that the session will last up to 30 minutes and will be held at the location that I am now working.

I understand that the research interviewer is not an employee of the company that I work for and that he will keep information abut me confidential by keeping all research data at a place other than on my employer's property. All data will be locked in a safe and secure place not on mg employer's property. Participation in this study will not affect my position with my employer or my position with the other manufacturing personnel. I further understand that publication of research results in any form will protect my privacy and disguise my identity by not using my name or videotape showing my face.

I understand that my involvement in the study will consist of participation in assembling a product and answering a demographic survey that will take no longer than 30 minutes. I am free to leave after the 30 minutes are up. My consent to participate also includes permission for James Dill to videotape my assembling the product that has been identified by him.

I understand that I may contact James Dill at any time during the course of the study if I have questions. I may contact James Dill at 831.338.2588.

I understand that my participation in this research is completely voluntary, and I understand that my signature below signifies my voluntary consent to my participation in this study. I understand that I may choose not to continue to assemble anytime during the study. I may also refuse to answer any of the demographic questions. I may withdraw fro the study at any time with no consequence to myself.

I have read the statements above and agree to take part in this study.

____

Research participant's Signature Date

____

Research's Signature Date