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INVESTIGATING THE EFFECTIVENESS OF REDUNDANT TEXT AND ANIMATION IN
MULTIMEDIA LEARNING ENVIRONMENTS

by

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A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Education
in the Department of Educational Research, Technology, and Leadership
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ABSTRACT

In multimedia learning environments, research suggests that simultaneous presentation of redundant text (i.e. identical narration and on-screen text) may inhibit learning when presented with animation at the same time. However, related studies are limited to testing with cause-and-effects content information (e.g., Moreno & Mayer, 1999, 2002).

This study examined the effects of redundant text on learners' memory achievement and problem solving ability. The study replicated and extended prior research by using descriptive, rather than cause-and-effect content information. The primary research questions were (a) does redundant text improve learning performance if learners are presented with instructional material that addresses subject matter other than cause-and-effect relationship? and (b) does sequential presentation of animation followed by redundant text help learning? To answer the research questions, five hypotheses were tested with a sample of 224 Taiwanese students enrolled in a college level Management Information System (MIS) courses at a management college in southern Taiwan.

Statistically significant differences were found in memory achievement and problem solving test scores between simultaneous and sequential groups; while no statistically significant differences were found in memory achievement and problem solving test scores between verbal redundant and non-redundant groups. These results were supported by interviewees expressing difficulty in connecting animation and verbal explanation in the two sequential presentation groups. The interview responses also helped to explain why insignificant results were obtained

when redundant and non-redundant verbal explanations with animation were presented simultaneously.

In general, the results support previous research on the contiguity principle (Moreno & Mayer, 1999), suggesting that sequential presentations may lead to lower learning performance when animation and verbal explanation are closely related. The separation of the two types of information may increase cognitive load. In addition, the study found that impairment of redundant text (Kalyuga, Chandler, & Sweller, 2004; Moreno & Mayer, 2002) was also affected by various learning characteristics, such as the structure of the instructional content and learners previous learning experiences.

Recommendations for future study include: (a) research on various situations such as characteristics of the content, characteristics of learners, and difficulty of the instructional material that influences the effects of redundant text, and (b) research on prior learning experience that influences the effects of simultaneous redundant text presentations.

This dissertation is dedicated to my wife Hsin-Ching who accompanies me in an unfamiliar place and to our families who have fully supported me and have made the completion of this project possible.

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LIST OF ACRONYMS/ABBREVIATIONS

| | |
|--------------|--|
| ANOVA | Analysis of Variance |
| CLT | Cognitive Load Theory |
| DFD | Data Flow Diagram |
| LTM | Long Term Memory |
| MANOVA | Multiple Analysis of Variance |
| MIS | Management Information System |
| Modified VVQ | Kirby, Moore, and Shofield's (1988) modified version of Richardson's Verbalizer-Visualizer Questionnaire (VVQ) |
| STM | Short Term Memory |
| VVQ | Verbalizer-Visualizer Questionnaire |
| WM | Working Memory |

CHAPTER ONE: INTRODUCTION

Bimodal presentations are commonly found in education. Books with radio, slides with audio tape, and television programs with closed captions all deliver two modes of information and are believed to help improve learning. New technology, such as computer-based multimedia, possesses the power to simultaneously present diagram, animation, narration, music, and on-screen text. Redundant presentation of identical text via auditory and visual channels is also common in instructional multimedia environments. Presenting redundant text in both audio and written forms has been influenced by “the more the better” concept that enables learners to be able to choose various information to best suit their learning needs (Brentrup, 1993; Townsend & Townsend, 1992).

According to information processing models of learning, *working memory* is a crucial element for learning (Miller, Galanter, & Pribram, 1960; Niaz & Logie, 1993). Working memory implies a system for temporarily holding information that is perceived. The human mind can hold small amounts of information for a very short time for cognitive tasks such as comprehension, learning, and reasoning (Shiffrin & Atkinson, 1969). Such limited capability keeps learners from processing large amounts of information through a single channel. For example, an inexperienced learner may not understand concepts when scanning a book for the first time. Because information in the book is new to the learner, a process of assimilation is needed. If working memory cannot process all the information immediately, the unprocessed information easily decays (Baddeley, 1998).

A means to improve working memory efficiency is bimodal presentation. It is believed that working memory has visual and verbal subsystems (Baddeley, 1998). Mental resources are distributed over separate auditory and visual channels, thus learners are better able to carry out two tasks if the two tasks involve different modalities rather than the same modality (Allport, Antonis, & Reynolds, 1972). Based on this hypothesis, a number of experiments investigated the effects of presenting auditory and visual information on retention by measuring instant recall of numbers or words. In general, researchers concluded that retention is greater if information is presented in bimodality than when only one modality is used (Frick, 1984; Hede, 1980; Lewandowski & Kobus, 1989, 1993).

Although redundant text has been found to benefit learning, the result may change when spatial information is added to multimedia content such as charts, diagrams, tables, pictures, animations, or video. This type of non-verbal information is usually considered more concise than equivalent textual statements (Levin & Mayer, 1993) and is often adopted in computer multimedia contents. However, a question arises when spatial information and redundant text are simultaneously presented to the learner. Are learners capable of processing spatial information and on-screen text at the same time? Because both spatial information and on-screen text are perceived through the visual channel, working memory may not be able to process the two types of visible information efficiently.

Similar considerations influence *cognitive load theory* (Chandler & Sweller, 1991) and *cognitive theory of multimedia learning* (Moreno & Mayer, 1999). Both theories assume learning can be enhanced by adjusting content appearances to meet the human working memory ability. Avoiding cognitive overload is the major consideration for designing instructional materials. Because working memory has its limitations, instructional materials should be structured to

eliminate any avoidable load on working memory to enhance learning (Kalyuga, Chandler, & Sweller, 1999). Redundant text may cause cognitive overload if other spatial information, such as animation and on-screen text, are simultaneously presented. Replacing redundant text with narration alone in multimedia presentations may result in better learning performance (Kalyuga, Chandler, & Sweller, 2004; Moreno & Mayer, 2002).

Studies indicate that learners presented with spatial information and narration outperform learners presented with spatial information and on-screen text (Mayer & Anderson, 1991; Moreno & Mayer, 2002; Mousavi, Low, & Sweller, 1995; Tindall-Ford, Chandler, & Sweller., 1997). A reasonable explanation is that spatial information and on-screen text share the same visual channel. The two competing visual objects cause some parts omission. Cognitive load theory refers to this situation as a *split-attention effect*; meaning that two types of visual information share the same cognition resource distracts learners' attention (Sweller & Chandler, 1994). For instance, when watching a television, some screen shots are easily missed when reading running text at the same time. The screen shots are missed because learners have the difficulty of paying attention to two screen zones.

Because multimedia contents tend to include multiple sources of information, studies that focus on the effectiveness of bimodal presentation have turned their attention to presenting redundant text and spatial information. Kalyuga et al. (1999, 2004) investigated learning effectiveness by mixing redundant text and diagram in their serial experiments. They reported split-attention occurred when simultaneously presenting diagram, narration, and on-screen text, which reduced learning performance. When they eliminated the on-screen text, a simultaneous presentation of diagram and narration produced more correct answers. Moreno and Mayer (2002) tested the conclusion by replacing animation with diagram in their multimedia intervention.

Similar to the means in which Mayer and his colleagues (Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994) used scientific cause-and-effect contents in their previous studies, Moreno and Mayer developed a multimedia material “how lightening is formed” as the experimental content. The study found a split-attention effect occurs when animation, narration, and on-screen text are presented simultaneously. The result agree with the previous studies that simultaneous presentation of redundant text and spatial information reduced learning performance; and it is ascribed to the split-attention effect which causes cognitive overload. They found simultaneous presentation of animation and narration generated higher learning performance in message retention and problem solving tests.

Another means to remove split-attention is presenting spatial information and on-screen text sequentially, thus the cognitive load is lowered (Kalyuga et al., 2004). Although sequential presentation can lower cognitive load caused by split-attention, it raises cognitive load by mentally retaining information. Because learners need to remember previous messages to connect successive messages, it breaks the reference connection between verbal explanation and spatial information (Mayer & Anderson, 1991). Cognitive theory of multimedia learning refers to the effect of connecting between non-verbal and verbal message as *contiguity principle* (Moreno & Mayer, 1999; Mayer & Moreno, 2002). The referential coordination can increase processing ability of working memory (Mayer & Sims, 1994; Mousavi et al., 1995; Paivio, 1991). Mayer and Anderson (1992) and Mayer and Sims (1994) reported this factor contributes an increase of memory achievement when simultaneously presenting animation and narration.

In general, studies suggest that redundant text improves learning when presenting in dual modality (Frick, 1984; Lewandowski & Kobus, 1993), but it impairs learning when presented with spatial information simultaneously because of split-attention effect (Kalyuga et al., 1999;

Mayer, Heiser, & Lonn, 2001; Moreno & Mayer, 2002). If spatial information and verbal explanation are needed, presenting spatial information and narration simultaneously has better memory achievement (Mayer & Anderson, 1992; Moreno & Mayer, 1999). The split-attention effect can be removed by sequential presentation, but sequential presentation can cause a break in message contiguity that may, in turn, impair memory storage (Mayer & Anderson, 1991). These findings depict a learning performance relationship between verbal redundancy and presentation sequence. Table 1 shows the learning performance changes under the different combination of verbal redundancy (redundant and non-redundant) and presentation sequence (simultaneous and sequential). Mayer and his colleagues used animation as spatial information to examine the usage of information modality by comparing verbal redundancy and presentation sequence (Mayer et al., 2001; Moreno & Mayer, 2002; Mayer & Sims, 1994). Moreno and Mayer (2002) found both verbal redundancy and presentation sequence have no statistical difference on memory achievement, problem solving, and matching tests. However, the interaction between verbal redundancy and presentation sequence shows the simultaneous presentation of animation and redundant text producing lower memory storage performance; a reversal effect is found (higher problem solving performance) when sequentially presenting animation and redundant text. The result generally supports the conclusions in literature.

Table 1:
Learning Performance Related to Verbal Redundancy and Presentation Sequence

| | Verbal Redundancy | Verbal Non-redundancy |
|--------------|--|--|
| Simultaneous | Animation, Narration, and On-screen Text <i>Lower Performance</i> (Mayer et al., 2001; Moreno & Mayer, 2002) | Animation and Narration <i>Higher Performance</i> (Mayer et al., 2001; Moreno & Mayer, 2002; Mayer & Sims, 1994) |
| Sequential | Animation followed by Narration and On-screen Text <i>Higher Performance</i> (Moreno & Mayer, 2002) | Animation followed by Narration <i>Lower Performance</i> (Moreno & Mayer, 2002; Mayer & Sims, 1994) |

Statement of the Problem

Although past studies on presenting redundant text and animation reported similar results, some questions remain. First, does redundant text improve learning performance if learners are presented with instructional material that addresses subject matter other than cause-and-effect relationship? The experimental intervention “how lightening is formed” is used in Mayer et al. (2001) as well as Moreno and Mayer (2002) studies. The subject course cause-and-effect relationship, knowledge of Cause-and-effect relationship possesses coherent structure with step-by-step operation explanations (Mayer & Moreno, 2002; Mayer & Sims, 1994). If learners omit some parts of the information, due to the split-attention effect, this condition could influence learners’ understanding and thus result in lower learning performance (Moreno & Mayer, 2002). While auditory narration may eliminate the split-attention effect and increase learning performance, other types of knowledge may generate a different result because some parts may

not affect others, as is the case with cause-and-effect subject matter. When using descriptive knowledge, for example, missing parts of information may not strongly affect learners continuing understanding. In addition, written text would greatly be needed in helping to understand descriptive content. Therefore, the effect of verbal redundancy needs to be examined with different types of knowledge to generalize the conclusion.

Second, does sequential presentation of animation followed by redundant text help learning? Studies indicate that simultaneous presentation of redundant text may reduce learning performance (Kalyuga et al., 2004; Sweller & Chandler, 1994). If identical audio and visual explanations with diagrams are used, redundant text should be presented sequentially to reduce cognitive load (Kalyuga et al., 2004). However, other studies reported increases in student learning when subjects were presented with auditory and written texts simultaneously. For example, Penney (1989) and Lewandowski and Kobus (1989, 1993) found redundant text helps learners to learn more efficiently than non-redundant text. Moreno and Mayer (2002) also reported that redundant text may enhance learning when animation and redundant text are presented sequentially. The effect of contiguity needs to be further tested when animation and redundant text are used.

Purpose of the Study and Hypotheses

This study examines the effectiveness of animation and redundant text in multimedia learning environments. To further understand how redundant text affects learning, the study was based on the interventions administered by Moreno and Mayer (2002), and extended intervention content and measurements. Specifically, the purposes of the study are to:

1. Examine whether animation and redundant text improves learning performances when with descriptive content. It is hypothesized that learners who receive verbal non-redundant explanation and animation will perform better on memory and problem solving tests than learners presented with animation and redundant text. The hypothesis is based on cognitive load theory (Sweller & Chandler, 1991) and cognitive theory for multimedia learning (Mayer & Moreno, 2002), which suggest that presenting animation and on-screen text simultaneously distracts learners visual attention, causing split-attention effect and thus inhibiting learning. It is assumed that verbal non-redundant explanation and animation more greatly increases learning performance than does animation and redundant text.
2. Examine whether sequential presentation of animation followed by redundant text improves learning performance. It is hypothesized that learners presented with animation followed by explanatory statement will perform worse on memory and problem solving tests than learners who are presented with simultaneous presentation. The hypothesized is based on cognitive theory for multimedia learning (Mayer & Moreno, 2002). Although split-attention effect can be removed by displaying animation and verbal explanation sequentially, the breaking message connection between animation and verbal explanation otherwise increases cognitive load (Moreno & Mayer, 1999).

Operational Definition

Verbal Redundancy

Verbal redundancy is a state of identical explanation text in two modalities. Redundant text regarded in this study is simultaneously presenting identical narration and on-screen text to learners. If a single modality is used for explanation, it will be considered as verbal non-redundant explanation. Because narration is considered a better means for delivering explanation statement (Mayer & Anderson, 1992; Moreno & Mayer, 1999), narration is referred to as verbal non-redundant explanation in this study.

Presentation Sequence

Presentation sequence in this study consists of simultaneous and sequential presentations. Simultaneous presentation regards two or more types of information, such as animation, narration, and on-screen text, are presented simultaneously to learners. Sequential presentation regards separate two or more types of information in before-and-after order. If three or more types of information are involved, sequential presentation may also include some types of information are presented simultaneously, such as animation followed by narration and on-screen text.

Memory Achievement

Memory achievement regarded in this study is the memorization performance after a short time period of learning, whereas Psychology studies use the term *retention* instead. This study uses memory achievement to emphasize the message storage ability. Because learning and

reasoning tasks relies on temporal message holding in working memory (Baddeley, 1998), measuring memory achievement is an index to understand participants' learning performance in memorization. This study focuses on the numbers of rules that learners remembered from what they have learned from the multimedia content.

Problem Solving

Problem solving in this study regards the creative abilities that learners used to solve other problems by applying on the knowledge of what they have learned from the instructional content. It shows how well learners developing their meaningful knowledge by the memorized information.

Significance of the Study

Like most technologies, advances in multimedia development are far outpacing research on its effectiveness. Modern authoring systems are making it easier for practitioners to develop multimedia products that combine audio, video, text and graphics in various ways. Intuitively, people believe that presenting people with all kinds of information will enhance learning. They believe this happens by stimulating multiple senses and addressing multiple learning styles. However, research suggests that presenting learners with both audio and redundant text when accompanied with other non-verbal information may cause cognitive overload and, thus, inhibit learning.

This study holds significance for instructional designers, educational researchers and the field of Instructional Technology. By replicating Moreno and Mayer (2002) study with different content and learning objectives, and adding a measure of learning styles, the results of

this study will: (a) either add further evidence for, or refute prior findings that suggest that presenting learners with spatial information and redundant text may inhibit learning; (b) either add further evidence for, or bring to question key principles associated with cognitive load theory; (c) help determine the generalizability of the results to alternative learning conditions (i.e., contents and objectives); and (d) help determine if an individual's cognitive style may have a moderating effect on related results.

Such findings will help instructional designers increase the effectiveness of multimedia training and educational applications by guiding key decisions regarding screen layout and contents. The results will also help educational researchers make important decisions regarding the nature of future studies related to multimedia learning and development, and will contribute to the knowledge-base associated with cognitive load theory and the field of Instructional Technology.

CHAPTER TWO: REVIEW OF LITERATURE

This chapter reviews literature related to each of the primary variables under the present study, including: (a) human memory for retention and cognition, (b) dual process proposition of working memory, (c) cognitive load for learning novel information, (d) studies of redundant text in multimedia presentations, and (e) discussion of influential factors.

In order to clarify the terms that are used in the study, a structure for instructional multimedia presentation is shown in Figure 1. Multimedia presentation includes verbal explanation and spatial information that are verbal and non-verbal information. The verbal explanation can be classified as redundant and non-redundant text, and redundant text includes narration and on-screen text (Figure 1). Because most of study findings which examining the effect of presenting redundant text and spatial information were based on using diagram or animation as the non-verbal part (c.f. Kalyuga et al., 2004; Moreno & Mayer, 2002), thus the term *spatial information* will be used as the general idea for animation and diagram in the present study (Figure 1). Although the present study is specifically focusing on examining the learning efficiency of using animation and redundant text, a broader discussion of related studies is needed to understand the effects of presenting verbal and non-verbal information.

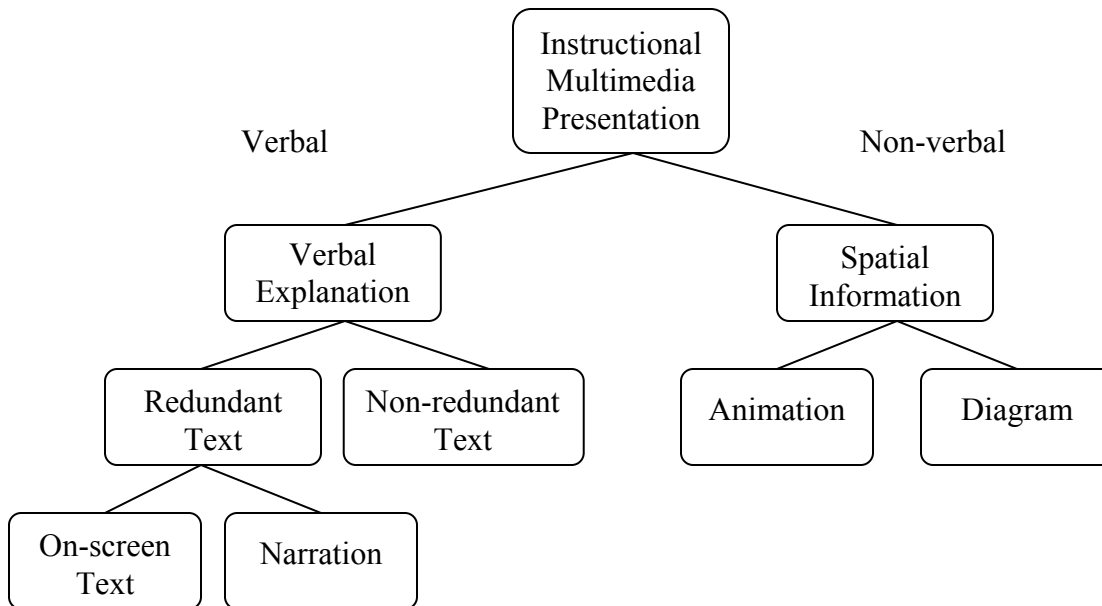


Figure 1: Modality Structure for Instructional Multimedia Presentation

Human Memory for Retention and Cognition

Retention and cognition are two primary factors associated with human learning (Baddeley, 1998). Cognitive theorists proposed a framework for describing human retention and cognition called the *information-processing model* (Waugh & Norman, 1965). The three basic components are: *sensory register (SR)*, *short-term memory (STM)*, and *long-term memory (LTM)*. Variations of the model are focus on structural components (e.g. memory stores for retention) (Shiffrin & Atkinson, 1969) and the flow of processing (related in cognition or learning) (Solso, 2001). Although there are variations of how learning occurs among information-processing models (c.f. Gagné & Driscoll, 1988; Mayer, 2002; Paivio, 1991), it is generally agreed that learning and memory are based on the flow of information that passes between the organic elements in the human brain (Solso, 2001; Sprinthall & Sprinthall, 1990). Sensors (e.g., eyes or

ears) respond to incoming information which is passed on to memory for encoding. The encoded information then travels between memory systems for processing and reshaping. Finally, it is stored for future retrieval and response (Gagné, Briggs, & Wager, 1992; Mayer, 2002; Simon, 1979; Solso, 2001; Sprinthall & Sprinthall, 1990). This basic model provides a theoretical foundation for understanding the influence of various modes on learning.

Sensory register serves as a device for encoding messages when the stimulus is received from the external environment. The encoded information is then sent to STM, for temporary storage. In STM, memory can be strengthened by organizing the information which is then passed on to LTM. If the information triggers memories in LTM then the information in STM can be processed with the retrieved information from LTM. Finally, the reshaped information is passed along and consolidated into LTM. The LTM is seen as a lifetime storage place for processed information (Gagné, Briggs, & Wager, 1992; Mayer, 2002; Solso, 2001; Sprinthall & Sprinthall, 1990).

In the process flow of information-processing models of learning, STM takes an important role in processing information; it connects between raw data (conversion from sensory register) and elite data (stored in long-term memory). Hence, STM is treated as a key factor in information-processing models (Miller, 1956; Miller et al., 1960; Niaz & Logie, 1993).

The Role of Working Memory

Short-term memory is mixed with features of both storage and processing. Two major fields focus on studying human memory; the term short-term memory is considered in terms of storage in behavioral psychology (Miller, 1956), whereas working memory is considered in

terms of its processing features in cognitive psychology (Baddeley, 1998; Solso, 2001; Mayer, 2002).

The limitations of STM cited in the literature include short duration and small capacity. Short-term memory holds information for about 1.5 to 2 seconds due to decaying memory (Baddeley, 1986, 1998). Some researchers believe that memory decay occurs as a result of the automatic fading of the memory trace (Waugh & Norman, 1965); while others believe the interference of the memory trace by another trace explains memory decay (Baddeley, 1998; Shiffrin & Atkinson, 1969; Solso, 2001). Besides the short duration, STM is also limited in storage capacity. Information can be held at limited amounts in the short-term memory. As Miller (1956) points out, an average of seven digits (plus or minus two) can be held. This indicates that human memory is unable to process huge amounts of information at the same time.

When STM serves an information processing function for cognitive tasks, it is often referred to as working memory (Baddeley, 1986, 1998; Gagné et al., 1992; Mayer, 2002). Cognitive psychologists consider working memory as a limited capacity system that could be used for storage or processing, but as storage demands increase, the resource available for processing decreases (Niaz & Logie, 1993). During thinking and reasoning, the interaction between storage and processing in working memory becomes a vital issue. Remembering seven digits in memory does not mean the human brain can process seven digits simultaneously. Researchers generally accept a digit span of up to three when engaging in information processing (Baddeley, 1998; Paas, Renkl, & Sweller, 2003), which limits human reasoning capabilities.

In general, related studies demonstrated the functions and limitations of working memory in learning. Working memory plays a key role between sensing and information storage in information-processing models (Miller et al., 1960; Niaz & Logie, 1993). Although working

memory has both storage and processing features, it has limitations (Baddeley, 1998). Limited resources restrain working memory from storing large amounts of information (Miller, 1956). When working memory functions as cognitive activities, such as reasoning and thinking, it requires less capability for processing information (Baddeley, 1998; Paas et al., 2003).

Dual Process Propositions of Working Memory

Because working memory is limited in duration and capacity, dual (audio and visual) processing may be an alternative to enhance learning. Researchers agree that there are multiple working memory stores rather than a solitary one (Baddeley, 1986, 1998; Mayer & Anderson, 1992; Paivio, 1991; Penney, 1989). Frick (1984) agrees with the idea of separated visual and auditory short-term memory, and the average digit span is ten when dual storage can be achieved, which exceeds what Miller (1956) reported of seven.

Dual processing studies use different terms, such as multiple stores, multiple channels, bisensory, dual-coding, or dual-processing, to describe visual and auditory processing (Allport et al., 1972; Morey & Cowan, 2004; Baddeley, 1986, 1998; Jones, Macken, & Nicholls, 2004; Mayer & Anderson, 1991; Paivio, 1971; Penny, 1989). Some studies use *mixed mode* to refer to visual and auditory items presented in sequential order and *bisensory* is used for auditory and visual items presented simultaneously to different sensory modalities (Penney, 1975). In earlier studies, the term *modality effect* referred to the finding that, in short-term memory tasks, auditory presentation almost always resulted in higher recall than did visual presentation (Penney, 1989). On the other hand, researchers found that bisensory processes improve memory performance. Hede (1980) reported higher recall in an experiment with bisensory presentation (audio and

visual list words in different semantic message) than with dichotic presentation (two audio list words in different semantic message).

The idea that presenting information as both spoken and written text improves learning is taken from the assumption that there are separate processing channels for visually and verbally presented items in human memory. Baddeley (1998) proposed a working memory model which consists of three components: (a) visuo-spatial sketch pad, responsible for handling non-language-based visual images, (b) phonological loop, responsible for handling language-based information, and (c) central executive, responsible for coordinating the visuo-spatial sketch pad and phonological loop. Utilizing partial autonomy for processing the visual and auditory information increases cognitive operation. This dual processing function helps learners take advantage of combining two modes of information. Because the two systems can be used simultaneously, limited working memory capacity can be effectively increased if the information can be presented partially in both modalities (Baddeley, 1998). This concept is similar to Paivio's (1971) *dual-coding theory*, although he places less emphasis on working memory and its limitations.

Dual-coding theory suggests that cognition consists of two separate but interrelated subsystems, verbal and nonverbal (Clark & Paivio, 1989). Information in the verbal subsystem is organized to favor sequential, syntactic processing. In contrast, nonverbal information (especially in the visual modality) is organized in holistically nested sets with information available for processing in a synchronous or parallel manner (Paivio, 1971, 1991). The mental processing ability may increase if information is presented in different forms (e.g. text and diagram) (Paivio & Lambert, 1981). Paivio (1991) implies that information can be processed using both auditory and visual channels. Thus, the advantage of bimodal presentations may

overcome the problem with large amounts of interacting elements in working memory when learning complex content (Gellevij, Van Der Meij, De Jong, & Pieters, 2002; Leahy, Chandler, & Sweller, 2003).

Dual-coding studies demonstrate increases in learning when two working memory subsystems are used instead of one (Frick, 1984; Gellevij et al., 2002; Leahy et al., 2003; Paivio & Lambert, 1981). Such studies conclude that learners can absorb information more efficiently by utilizing both audio and visual presentations, rather than one or the other. However, the bimodal advantage has its limit; the two working memory subsystems share processing resources. If visual and verbal messages are not interrelated, it decreases working memory performance (Morey & Cowan, 2004). On the other hand, cognition performance can be improved by simultaneously presenting interrelated nonverbal and verbal information (Mayer & Anderson, 1991; Tindall-Ford et al., 1997), or identical narration and written words (Allport et al., 1972; Levin & Divine-Hawkins, 1974). These findings help to better understand the characteristics of working memories.

Cognitive Load for Learning Novel Information

When inexperienced learners acquire new knowledge, the learning process requires both processing and storage functions of working memory (Sweller & Chandler, 1994). Because learning novel information relies heavily on working memory, learners may be required to engage in information processing that exceeds working memory capacity. As a result, understanding, learning, and problem solving may be hindered (Kalyuga et al., 1999; Sweller, van Merriënboer, & Paas, 1998). Limited by working memory resources, researchers seek solutions that manipulate external representation to meet the limitations of the human mind.

Many studies, especially in science education, have been based on ‘working memory overload hypothesis’ (Niaz & Logie, 1993). Studies such as cognitive load theory (Chandler & Sweller, 1991; Sweller & Chandler, 1991) and cognitive theory of multimedia learning (Mayer & Moreno, 2002) indicate that mental load is an important factor that affects human learning. From the working memory point of view, information that exceeds processing capability is less effective (Mayer, 2003). If information flow can be maintained within a workable level by adjusting the external representation (how knowledge is presented), working memory may increase learning performance (Sweller & Chandler, 1994). This is the fundamental assumption of cognitive load theory and cognitive theory of multimedia learning.

Cognitive Load Theory

Cognitive load theory (Chandler & Sweller, 1991; Sweller & Chandler, 1991) describes learning activities in terms of information processing models of cognition. It is based on the assumptions that: (a) cognitive tasks are performed in working memory (Shiffrin & Atkinson, 1969), (b) working memory includes auditory and visual working memory (Paivio, 1991), (c) each working memory has a limited capacity (Baddeley, 1986; Miller, 1956). Sweller and Chandler (1994) argue that learning requires working memory to actively engage instructional material (elements) that interacting with each other. Nevertheless, working memory is limited in both capacity and duration. The information should be structured to eliminate any avoidable load on working memory to enhance learning (Kalyuga, Chandler, & Sweller, 1998). In another word, control information flows into working memory in a workable size by adjusting the appearance of the content (Chandler & Sweller, 1991).

Cognitive load theory suggests that knowledge (or information) can be divided as *intrinsic* and *extraneous* cognitive loads (Sweller et al., 1998). Intrinsic cognitive load is determined by the knowledge itself (interactivity memory elements in working memory), while extraneous cognitive load is determined by the appearance of the content (instructional design) (Carlson, Chandler, & Sweller, 2003). When a task does not involve an intrinsically high cognitive load, how the information is presented may be less important (Kalyuga et al., 1998). With a low intrinsic cognitive load, the student may have sufficient cognitive resources to cope with an extraneous cognitive load if working-memory capacity is not exceeded (Cooper, 1998) (Figure 2).

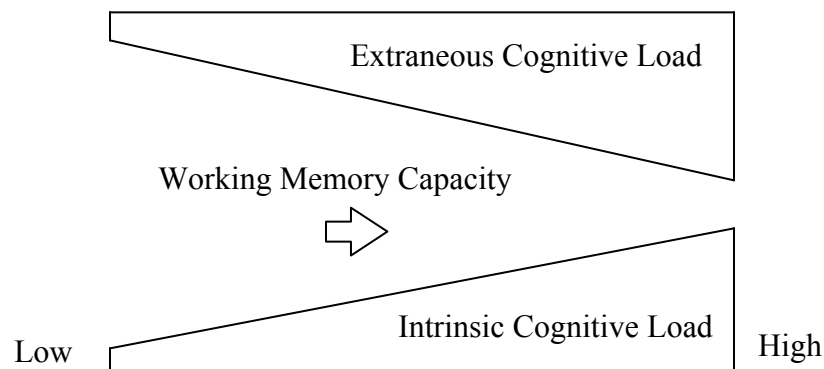


Figure 2: Relationship for Intrinsic Cognitive Load, Extraneous Cognitive Load, and Working Memory Capacity

In contrast, when a task involves an intrinsically high cognitive load, it is important that the information be represented in a way that reduces the extraneous cognitive load to make it easier to understand (Paas & van Merriënboer, 1994). An intrinsically high cognitive load cannot be altered, but total cognitive load can be reduced by the elimination of any extraneous cognitive

activities. The extraneous cognitive load is generated by the format of content that can be reduced by how information is constructed and communicated (Tindall-Ford et al., 1997). Instructional manipulations can reduce the extraneous cognitive load, and this reduction may be critical when the material imposes an intrinsically high cognitive load (Paas et al., 2003; Sweller et al., 1998).

Cognitive load studies have developed several principles for reducing intrinsic and extraneous cognitive load (Sweller et al., 1998; Sweller & Chandler, 1994; Paas et al., 2003; Valcke, 2002). For instance, the redundancy, split-attention, and modality effects are the primary principles related to the study of presenting spatial information and redundant text in computer multimedia environments (Kalyuga et al., 1999, 2004; Mayer, 2003; Moreno & Mayer, 2002).

Redundancy Effect

When communicating complex knowledge, the use of visual representation, especially text and diagrams, are often considered. The redundancy effect develops when spatial information is presented with explanatory statements (e.g. Chandler & Sweller, 1991; Sweller & Chandler, 1994); for example, when a diagram with words explains a geometry question. The redundancy effect occurs when two sources of information can be understood independently, and each source provides similar information but in different forms (Kalyuga et al., 1998). If multiple sources of information can be understood in isolation but are presented simultaneously, unnecessary interactivity between visual and audio memory may decrease learning performance (Sweller & Chandler, 1994). When learners can understand with one mode of information, presenting duplicated information will causes extraneous cognitive load (Sweller et al., 1998). Thus, redundant information from two sources (e.g. figure and text) can distract learners.

Split-attention Effect

Extraneous cognitive load is not only affected by redundant information, it is also caused by two forms of information that cannot be integrated together in working memory. This situation is referred to as the *split-attention effect*. Split attention is usually found in visual materials, when text and diagrams are placed in different locations. The learner has to search between two areas to mentally integrate the two resources of information. Under such condition, an unnecessary working memory load is caused not by learners having to split their attention between multiple sources of information, but by the very existence of multiple sources of information (Kalyuga et al., 1998). Closed captioning on television, for instance, is a typical case of redundant text with video. Visual working memory is responsible for processing two different forms of information: video and subtitled text. Such conditions are also seen on multimedia materials. When a multimedia presentation is used, presenting pictures or animations with on-screen text can also create a split-attention effect. The learners must look at both types of information at the same time, thereby, missing out on parts of the presented material (Mayer, & Moreno, 2002).

If the content consists of a figure and text, problems with cognitive load may be solved by physically integrating the figure and text together, thereby lowering the split-attention effect (Sweller & Chandler, 1994). However, Chandler and Sweller (1991) demonstrated that if redundant sources of information are integrated, the effects can be negative rather than positive. Processing a redundant piece of information requires cognitive resources. If the redundant information is integrated physically with essential information, there is no choice but to process it. Extraneous cognitive load is imposed, and so integration may have negative effects. Moreno

and Mayer (2002) examine the learning effectiveness of mixing redundant text and animation. They have concluded that (a) achievement is impaired when simultaneously presenting spatial information and redundant text, (b) achievement is improved when spatial information and redundant text are presented separately, and (c) the split-attention effect explains both causes.

Furthermore, it is impractical to physically integrate text into moving pictures such as video or animation. Even reduced words proved to hinder learning, when narrated animations were integrated with identical on-screen text or summary text (Mayer et al., 2001). When content is presented with moving pictures such as animation, on-screen text shown at the bottom of the computer screen became a problem for learners. The learner needs to read text from the bottom, hold the information, and then look to the middle of the screen to find the corresponding animation and mentally integrate the texts and visuals. The unnecessary working memory load is caused not only by learners having to split their attention between multiple sources of information, but rather, by the very existence of multiple sources of information (Kalyuga et al., 1998). Thus a better solution is to use audio for explanatory statement instead of on-screen text (Moreno & Mayer, 2002).

Modality Effect

The *modality effect* occurs under split-attention conditions when a written source of information, such as an on-screen text, is presented in an auditory rather than a written mode when integrated with another source of non-verbal information such as a diagram (Sweller et al., 1998; Tindall-Ford et al., 1997). Early research has proved the superiority of dual processing (Baddeley, 1986; Hede, 1980; Paivio, 1991; Penney, 1989). Recent studies also found that narration is superior than on-screen text if it is accompanied by other spatial information

regardless of whether it is a diagram or animation (Gellevej et al., 2002; Leahy et al., 2003; Mousavi et al., 1995; Sweller et al., 1998; Moreno & Mayer, 2002).

Although related studies show the superiority of the modality effect, the result is limited to certain conditions. Mousavi et al. (1995) investigated presentation sequence, split-attention, and modality effects in their experiments. They tested split-attention and modality effects by comparing three groups: simultaneous group use of diagram, printed text, and audio tape; visual-visual group use of diagram and printed text; and visual-auditory group use of diagram and audio tape. The results demonstrated greater performance in mixed modality groups (simultaneous and visual-auditory) than the visual split-attention group (visual-visual), while no difference in performance was found between simultaneous and visual-audio groups. Mousavi et al. (1995) then tested whether the advantage of modality effect exists if a diagram and an audio tape are presented sequentially. They paired visual-visual and visual-auditory information to compare the effects of simultaneous and sequential presentations. Results suggested that sequential presentation of visual and auditory material does not eliminate the benefit of the modality effect. In other words, bimodal advantages occur both in simultaneous and sequential presentations.

However, Mayer and Anderson (1992) obtained contrasting results. They found that bimodal presentation may be superior in problem solving performance only when the visual and audio information are presented simultaneously rather than sequentially. Mousavi et al. (1995) ascribed the contradicting results to information segmentation. They used a technique called “worked example” in smaller information segments to explain geometry questions, whereas Mayer and Anderson’s experimental content contained larger information segments to explain scientific cause-and-effect functions. Mousavi et al. (1995) indicated that small information

segments occupy fewer working memory resources for retaining information in sequential presentation; hence the advantage of bimodal presentation is preserved. Jeung and Chandler (1997) examined this condition by using a reverse method--overloaded working memory. They use complex geometry shapes which require heavy visual activity. The study found that modality advantage exists only if mental resources are not devoted to extensive visual search activities involved in the coordination of auditory and visual materials.

In addition to the amount of information, learning time is another factor influencing the result of modality effect. Tabbers, Martens, and van Merriënboer (2004) indicated that cognitive load may be decreased by extending the learning time in a classroom setting. They found modality effect may not have a significant effect on learning performance if instructions are learner-paced instead of system-paced. To utilize animation for explaining complex knowledge, and to avoid the effects of learner-paced instruction, studies such as Mayer, Moreno, Boire, and Vagge (1999) and Kalyuga, Chandler, and Sweller (1999, 2000) presented their experimental content with system-paced animations.

The results from Mayer and Anderson (1992), Mousavi et al. (1995), and Tabbers et al. (2004) provide additional insights into the modality and split-attention effect. It appears that modality effect retains if presenting explanatory statement with small segments regardless of text redundancy and presentation order (Mousavi et al., 1995). In addition, extending learning time by using learner-paced multimedia instructions also decreases the modality effect (Tabbers et al., 2004). Small segmenting and learning time are the two factors that influence presentation interventions.

Cognitive Theory of Multimedia Learning

Based on the dual-coding theory, cognitive load theory, and the results of a series of empirical studies, Mayer and Moreno (2002) present a cognitive theory of multimedia learning to help guide the design of instructional multimedia materials. The empirical studies used animations with explanations illustrating scientific contents, such as how a bicycle pump works (Mayer & Anderson, 1991), how a braking system works (Mayer & Anderson, 1992), how lightning is formed (Mayer et al., 2001; Moreno & Mayer, 1999, 2002), and how the human respiratory system works (Mayer & Sims, 1994). In other words, these empirical studies focus specifically on the cognition of animations and on-screen text for scientific cause-effect contents (Mayer et al., 2001; Mayer & Moreno, 2002); these differ from other researchers who focus on cognition of diagrams and text (Chandler & Sweller, 1991; Kalyuga et al., 1998; Sweller & Chandler, 1994).

The cognitive theory of multimedia learning developed from the application of animations, narration, and on-screen text shares similar principles with cognitive load theory. For example, cognitive theory of multimedia learning also discusses the principles of split-attention and modality, except in the area of animation and on-screen text (Mayer & Anderson, 1992; Moreno & Mayer, 1999).

Although the two theories share similar arguments, the cognitive theory of multimedia learning helps to explain phenomenon that is not addressed by cognitive load theory, such as the contiguity effect. The contiguity effect suggests that the simultaneous presentation of explanatory statements and animation helps learners cross reference the two forms of information (Mayer & Sims, 1994). Specifically, the contiguity effect posits that problem solving performance is enhanced when spatial information and explanatory statements are either physically integrated

(written text and spatial information) or simultaneously presented (narration and spatial information) rather than separated (Moreno & Mayer, 1999). The knowledge of using animation and the contiguity effect provide another facet for optimizing learning in a multimedia environment.

The concept of cognitive load is important for instructional designers because of the emergence of computer multimedia which allows for diverse presentations (Marcus, Cooper, & Sweller, 1996; Mayer et al., 1999; Sweller & Chandler, 1991). In general, the cognitive load studies report a mixed effect between split-attention and modality; the conclusions of split-attention, modality, and contiguity are found under particular conditions. Cognitive load theory (Sweller & Chandler, 1991) and cognitive theory of multimedia learning (Mayer & Moreno, 2002) suggest that splitting the attention between on-screen text and other visual information causes learners to skip important information which impairs learning (Kalyuga et al., 1999; Moreno & Mayer, 2002). The modality principle suggests using narration instead of on-screen texts to eliminate the split-attention situation which improves learning (Leahy et al., 2003; Sweller et al., 1998; Tindall-Ford et al., 1997). The contiguity effect indicates if learners are forced to simultaneously hold spatial information and text in visual working memory, they are less able to devote attentive resources to building connections between them (Chandler & Sweller, 1991; Moreno & Mayer, 2002). The students' problem solving performance can be enhanced only when animation and narration is presented simultaneously (Mayer & Anderson, 1991, 1992; Moreno & Mayer, 2002); whereas there is no retention performance difference when animation and narration is presented sequentially (Mayer & Anderson, 1991, 1992).

Studies Related to Redundant Text in Multimedia Presentations

Many redundant text studies in terms of multimedia presentation are also related to cognitive load, and these studies reveal divergent results. Some studies demonstrate the limitation of redundant text (Kalyuga et al., 2004; Moreno & Mayer, 1999, 2002; Tindall-Ford et al., 1997). Others showed no difference in learning achievement and completion time when an explanatory statement was presented in redundant and verbal non-redundant explanation (Barron & Kysilka, 1993; Barron & Atkins, 1994). Still others noted a redundant text advantage exists when cognitive load is reduced (Lewandowski & Kobus, 1993; Mousavi et al., 1995). Obviously, the advantage or disadvantage of displaying redundant text depends on various conditions. Presenting redundant text and spatial information is common in multimedia presentations (Kalyuga et al., 2004; Mayer et al., 2001; Moreno & Mayer, 2002). Redundant text represents an verbal explanation by using identical words in both visual (on-screen text) and auditory (narration) modalities. A verbal explanation is accompanied by spatial information simultaneously, such as redundant text and animation, to provide another direction of information. Such configuration is common in multimedia environments, and is considered beneficial for learning (Mayer & Anderson, 1992; Moreno & Mayer, 2002).

Although simultaneous presentation of redundant text and spatial information is intuitively considered to benefit learning, the results diverge in empirical research. Studies argue that because the competition between on-screen text and spatial information requires learners to split attention between video and on-screen texts, it might cause skipping of some important information (Kalyuga et al., 1999, 2004; Moreno & Mayer, 2002). Difficulties resulting from the presentation of on-screen text in the past studies fall mostly into sharing visual resources with

spatial information (Kalyuga et al., 2004; Sweller et al., 1998). There are two conditions found in related studies when adding on-screen text in multimedia presentations. If both on-screen texts and spatial information can be understood by independently, the redundant cognitive process decreases available working memory sources (Kalyuga et al., 1999). On the other hand, if both on-screen texts and spatial information need to cross reference each other, the two visual information sources causes a split in learners' attention (Kalyuga et al., 2004; Moreno & Mayer, 2002). Both conditions create cognitive overload within learners; unnecessary working memory activities thus reduce learning capabilities (Kalyuga et al., 1999; Sweller et al., 1998).

A solution for avoiding the split-attention effect is using audio as an explanatory statement. In the related literature, simultaneously presenting narration and spatial information fits cognitive load principles for designing multimedia presentation: avoid the competition from on-screen text and spatial information to eliminate the split-attention effect (Kalyuga et al., 1999); apply information through different sensory channels to enhance the modality effect (Mousavi et al., 1995); and establish the referential connection between verbal and nonverbal information to create the contiguity effect (Mayer & Anderson, 1992). There is also a trend showing that narration is a better solution instead of on-screen text when simultaneously presenting an explanatory statement and spatial information (Mayer & Anderson, 1991; Moreno & Mayer, 2002; Mousavi et al., 1995; Tindall-Ford et al., 1997).

Another means to avoid split-attention effect by using sequential presentation has been examined in the literature. If the simultaneous presentation of redundant text and spatial information causes cognitive overload, splitting them up and presenting them sequentially seems logical to reduce working memory load. However, related studies that compare simultaneous and sequential presentations indicate that the performance of sequential presentations were inferior to

simultaneously presented information (Mayer & Anderson, 1991; Mayer et al., 2001). The lower performance result is due to the absence of contiguity: a lack of building representational connections between spatial information and verbal explanation (Mayer and Anderson, 1992). In a sequential presentation, learners need to remember previous messages to connect successive messages; successive information breaks the referential connection between spatial information and verbal explanation (Mayer & Anderson, 1991).

A study combining verbal redundancy and presentation sequence shows preliminary findings of using redundant text and animation in multimedia environments (Moreno & Mayer, 2002). The study used multimedia content, “how lightning is formed,” testing participants’ performance with various combinations of on-screen text, narration, and animation. The first experiment tested (a) whether redundant verbal text (on-screen text and narration) promotes better learning performance than redundant text (narration), and (b) whether animation promotes better learning performance than no animation is presented. The results indicated that simultaneous redundant text outperformed narration alone on retention and transfer tests. The group who received animation followed by explanatory statement outperformed the group that received explanatory statement only on retention and transfer tests. The results support the hypothesis that learners presented with simultaneous redundant text presentation will perform over learners presented with sequential redundant text presentation, adding further evidence to support Mayer & Anderson’s (1991, 1992) findings, but contradicting the results obtained by Mousavi et al. (1995). Mousavi et al. found no difference in presentation sequence (simultaneous and sequential). They explain the contradiction is because small chunks of information were presented to learners instead of large blocks, as presented in Mayer and Anderson’s study, thus reducing cognitive load.

The advantage of presenting redundant text and animation in Moreno and Mayer's (2002) first study leads to the following question: does redundant text and animation presented together also promote learning? Their second experiment tested (a) whether redundant text advantage still remains with the addition of animation, and (b) whether the split-attention effect occurs when all three modes of information (i.e. narration, on-screen text, and animation) are presented simultaneously. The results were consistent with the previous study presumably due to the split-attention effect. A study by Kalyuga et al. (2004) resulted in similar findings. They found that the simultaneous presentation of redundant text and diagrams produced lower learning performance than non-redundant text and diagrams. However, Kalyuga et al. suggest that redundant text lead to decreases in learning only when diagrams create high cognitive load; whereas diagrams with low cognitive load with redundant text neither help nor impairs the learning.

The cognitive load and redundant text studies demonstrate two primary presentation factors, text redundancy and presentation sequence, that are influence learning. However, the research finding displayed in literature also reveals a number of factors that need to be addressed, such as animation presentation, time on task, information segmentation, prior knowledge, and learning style. These factors need to be accounted for influencing the two primary presentation elements in future study.

Discussion of Influential Factors

In addition to various configurations of multimedia presentation that affect learning performance, the present study also takes into account other factors that influence the results.

An animation with high intrinsic cognitive load of spatial information needs to be used for examining the effectiveness of redundant text. In a multimedia environment, animation may

be one of the primary information means of communicating to learners. However, because scientific animations may also create high intrinsic cognitive load (Moreno & Mayer, 2002), a method to reduce extraneous cognitive load is needed. Although Mayer and his colleagues have investigated the use of animation in their studies (c.f. Mayer & Anderson, 1991, 1992; Mayer & Sims, 1994; Mayer et al., 1999; Moreno & Mayer, 1999, 2002), they have limited their studies of redundant text and animation to a single multimedia instruction “how lightning is formed.” Thus further examining the conditions of using redundant text accompanied by animation in multimedia instructions is needed.

Three major factors need to be avoided when examining the effectiveness of different presentations. These three factors greatly influence learning performance in the literature: information segmentation, learning time and prior knowledge. Information segmentation influences working memory processing load when receiving information. If the information segments are too small, the effects of inefficient presentation will be compensated by using free working memory resources (Mousavi et al., 1995). Time on task may also influence working memory load. If learners receive high cognitive load information, extending learning time may reduce the effect of working memory overload (Tabbers et al., 2004). Prior knowledge is another factor influence learning performance. Either high or low intrinsic cognitive load depends on learner’s prior knowledge. If the content is regarded as novel information to learners, the information is considered as containing high intrinsic cognitive load (Kalyuga, Chandler, & Sweller, 2001).

Learning style is another factor that may influence the research of presenting learners of explanatory statements and animation. Multimedia presentation requires learners to process information presented in different modes (e.g., visual and verbal). Although most individuals are

capable of using two modes of representation (i.e., visual or verbal), there are some individuals who have a tendency to use either visual or the verbal (Riding & Cheema, 1991). This type of individual aptitude is called *learning style*. Learning style can be described as the extent of message dependency--an individual means of processing information (Plass, Chun, Mayer, & Leutner, 1998). Studies have demonstrated that the learning style is correlated with verbal and spatial ability (Hale, Myerson, Rhee, Weiss, & Abrams, 1996; Kirby, Moore, & Shofield, 1988).

This chapter reviewed literature related to the presentation of redundant and spatial information to learners and its effects on human learning and performance. The convergence of related studies draws a framework for the intensive study of the redundant text in multimedia environments. In summary, related studies suggest that redundant text impairs learning when accompanied spatial information (Kalyuga et al., 2004; Moreno & Mayer, 2002). To enhance learning by presenting explanatory statement and spatial information together (Mayer & Anderson, 1992), narration rather than on-screen text, yields better results in learning (Leahy et al., 2003; Mayer & Anderson, 1991; Moreno & Mayer, 2002; Tindall-Ford et al., 1997). Furthermore, redundant text outperformed verbal non-redundant explanation when content is presented in sequential order, but the result was opposite when material is presented simultaneously (Moreno & Mayer, 2002). To generalize conclusions regarding the effects of redundant text, various measurements, conditions, and experimental contents are must be further tested. This study is to examine the preliminary conclusions in this chapter, but with different intervention content to acquire learning performance of memory achievement and problem solving. For avoiding the effect form verbal and visual learners, this study will be taken account of balancing different learning styles.

CHAPTER THREE: STUDY METHOD

Chapter three describes the study method including participants, sample size selection, research design for answering the two primary study questions, intervention design, instruments, experimental procedures, data analysis, and limitations.

Participants

The participants were freshmen, sophomores, and juniors in the Department of Information Management at the Daiwan College of Management, Taiwan. All participants were 18 years or older. Most high school graduates are accepted by colleges or universities according to the scores of the Joint College Entrance Examination in Taiwan. Hence the learning achievement is homogeneously distributed in a college.

Three hundred twelve students were recruited and given the Modified VVQ questionnaire. Seventy-eight participants were distributed into four different intensity groups based on the Modified VVQ index numbers, then randomly selected from the four groups into four treatment groups to attend the instruction and test phase. Two hundred thirty six participants completed the instruction and the two tests.

Results from three of the 236 participants were not used due to incomplete or missing data. Only 4 out of the 233 case were in higher verbal cognition (among -3 and -5 of intensity); the 4 cases were removed from the analysis process due to insufficient sample size. Of the 229 sample, 57 were made up the group of simultaneous presentation of animation, narration, and on-screen text (ANT), 59 were made up the group of simultaneous presentation of animation and

narration (AN), 57 were made up the group of sequential presentation of animation followed by narration and on-screen text (A-NT), and 56 were made up the group of sequential presentation of animation followed by narration (A-N). Fifty-six cases were randomly selected from each group to equalize sample size between groups. The resulting 224 cases (4 groups, 56 cases each) were used for testing the hypotheses and answering the research question posed in this study.

The level of statistical significance for the study was set at the conventional value $\alpha = .05$ (two tailed). To achieve the statistical power of .80 ($1-\beta = .80$) in the study, the effect size was defined at medium ($\Delta = .40$) for ANOVA tests (Cohen, 1992).

Research Design

This study examines the effects of redundant text on learning when presented with animation. The effects of redundant text will be tested in two ways: verbal redundancy and presentation sequence. Verbal redundancy is to compare between verbal redundant and non-redundant with simultaneous and sequential presentations (Table 2). Presentation sequence is to compare between simultaneous and sequential with verbal redundant and non-redundant presentations (Table 2).

Table 2:
Presentations for Verbal Redundancy and Presentation Sequence

| Presentations | |
|-----------------------|---|
| Verbal Redundancy | |
| Redundant | Simultaneous redundant & Sequential redundant |
| Non-redundant | Simultaneous non-redundant & Sequential non-redundant |
| Presentation Sequence | |
| Simultaneous | Simultaneous redundant & Simultaneous non-redundant |
| Sequential | Sequential redundant & Sequential non-redundant |

To test the effects of the four different type presentations, animation with verbal explanation (narration and on-screen text) were used in this study. Table 3 shows the intervention matrices of the four presentations by using different combination of animation, narration, and on-screen text.

Table 3:
Intervention Matrices of the Four Presentations

| | Verbal Redundant | Verbal Non-redundant |
|--------------|--|---------------------------------|
| Simultaneous | Animation, Narration, and On-screen Text | Animation and Narration |
| Sequential | Animation followed by Narration and On-screen Text | Animation followed by Narration |

Table 4 illustrates the research design that was used to test the two primary research hypotheses. Due to previous study results demonstrating that the learning performance of animations presentation is stronger for high- than for low-spatial processing ability learners (Mayer & Sims, 1994), the experiment may have contradictory results if individual learning differences are not considered. Hence, participants' individual differences of cognitive style were measured to balance individual learning differences between the four intervention groups. To remove possible influence from participants' information processing differences, the study used the stratified random sampling method for balancing the four groups (Table 4) based on the measurement of visual or verbal cognitive style.

There are four independent variables of the study: (a) simultaneous presentation of animation, audio narration, and on-screen text, represented as symbol X_1 ; (b) simultaneous presentation of animation and audio narration, represented as symbol X_2 ; (c) sequential

presentation of animation followed by audio narration and on-screen text, represented as symbol X_3 ; and (d) sequential presentation of animation followed by narration, represented as symbol X_4 . Memory achievement and problem solving tests (O_{ab}) were measured for each intervention. To avoid competition between animations and on-screen text, narration was used as non-redundant text. The two dependent variables are rote memorization and meaningful learning, and were measured with memory achievement and problem solving tests respectively.

Table 4:
Research Design

| | |
|---|----------------|
| R | $X_1 — O_{ab}$ |
| R | $X_2 — O_{ab}$ |
| R | $X_3 — O_{ab}$ |
| R | $X_4 — O_{ab}$ |

Instruments

Instructional Materials

The instructional material “Understanding Data Flow Diagram” (Appendix G) was a computer-based instructional module which created by Macromedia Flash MX. The primary objective is for MIS students to learn how to use a tool for analyzing data flow. Originated from of the book “Modern Systems Analysis Design” (Hoffer, George, & Valacich, 1999, p242-248), the instructional content contains rules and organized information that are presented with

animation and verbal explanations (narration and on-screen text). To control for improvement effects that may result from increased time in tests, participants were prohibited from stopping or replaying the presentation. The content provides high cognitive load to participants because they do not have prior knowledge of the content.

The instructional time varied between 10 and 20 minutes (depending on simultaneous or sequential presentation) with 37 sub-sections of animation. The narration pace was set between 160 and 180 words per minute, which is within the ideal range of memory recommended by Schlater (1970).

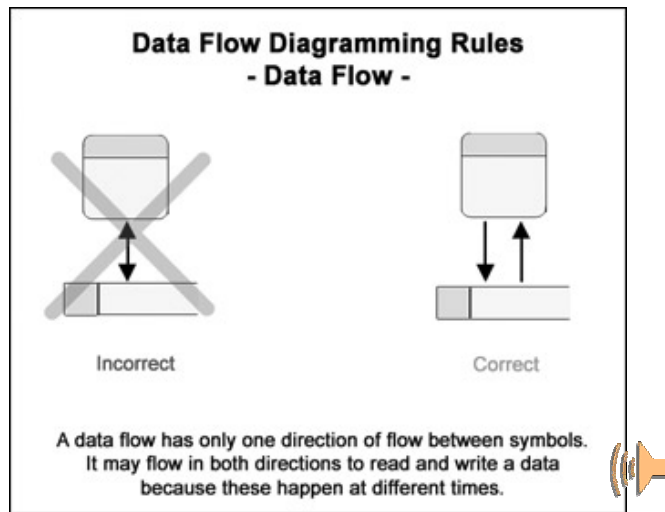
Mandarin writing in Traditional Chinese is the official language in Taiwan. Due to native language differences which may affect the results, the narration of the instructional material was translated into Mandarin and on-screen text was translated into Traditional Chinese. The content validity for both instructional material versions was evaluated by two MIS related course instructors in the Department of Information Management, Daiwan College of Management.

Interventions

The study was designed to examine the effects of verbal redundancy and presentation sequence on learning performance. Four interventions were used in this study with different combinations of animation, narration, and on-screen text. The four different modules are attributed as verbal redundancy which includes simultaneous redundant and non-redundant text presentation (Figure 3), and presentation sequence which includes sequential redundant and non-redundant text presentation (Figure 4).

Legend:  (Narration)

Simultaneous Redundant Text Presentation (Animation, Narration, and Text)



Simultaneous Non-redundant Text (Animation and Narration)

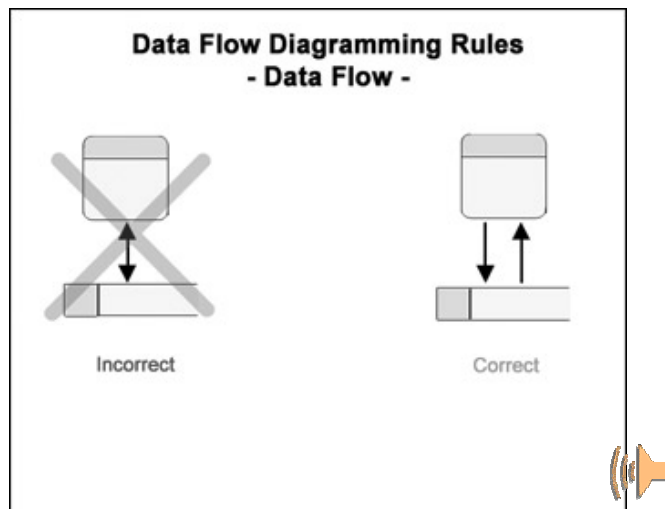
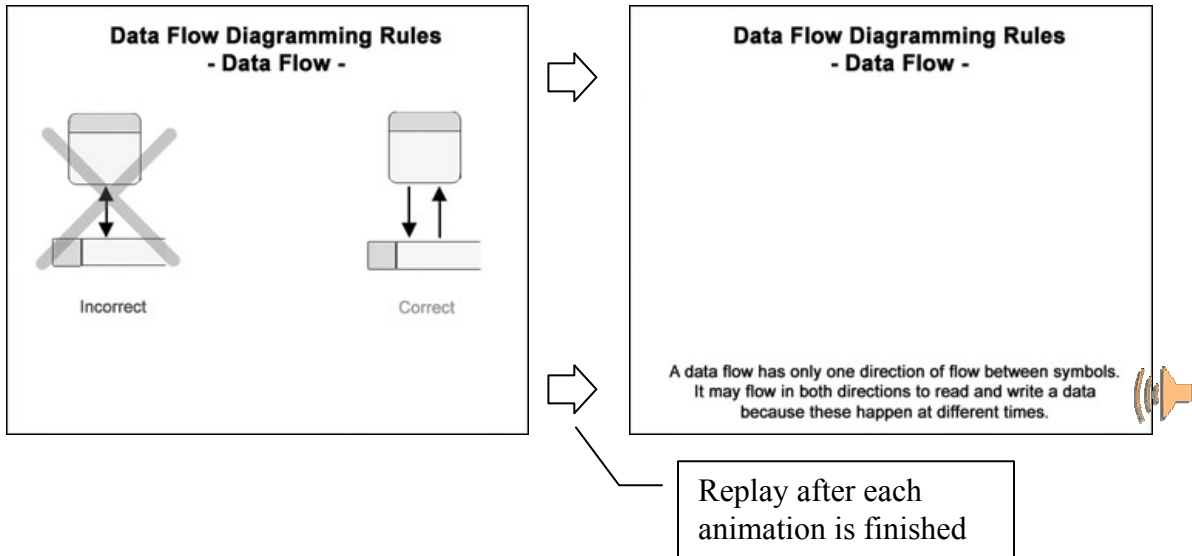


Figure 3: Instructional Modules for Verbal Redundancy

Legend:  (Narration)

Sequential Redundant Text Presentation
(Animation Followed by Narration and On-screen Text)



Sequential Non-redundant Text Presentation
(Animation Followed by Narration)

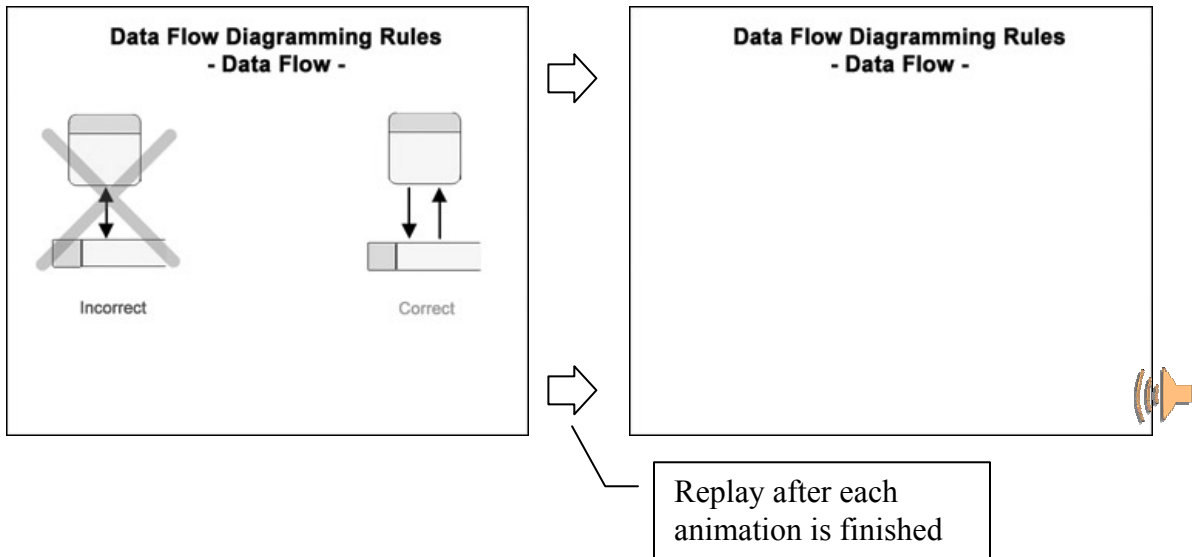


Figure 4: Instructional Modules for Presentation Sequence

Acronyms used to distinguish the intervention are as follows: (a) animation with narration and on-screen text (ANT group), which represents simultaneous redundant text presentation; (b) animation with narration (AN group), which represents simultaneous non-redundant text presentation; (c) animation followed by narration and on-screen text (A-NT group), which represents sequential redundant text presentation; and (d) animation followed by narration (A-N group), which represents sequential non-redundant text presentation.

Instruments

Three instruments were used to gather data: the Modified Version of Richardson's Verbalizer-Visualizer Questionnaire, a memory achievement test, and a problem solving test. The Modified Version of Richardson's Verbalizer-Visualizer Questionnaire was used to measure participants' cognitive style. The memory achievement and problem solving tests were used to measure participants' learning performance. All three instruments were translated into Traditional Chinese and reviewed for content validity by two related course instructors in the Department of Information Management, Daiwan College of Management.

Modified Version of Richardson's Verbalizer-Visualizer Questionnaire

Kirby's (Kirby et al., 1988) modified 20-item version of Richardson's Verbalizer-Visualizer Questionnaire (VVQ) was used as an index to identify whether the learner tends to process with spatial or verbal information (Appendix C). The 20-item scale of modified VVQ consists of ten verbal and ten visual true or false items.

Kirby's modified VVQ computed the reliability (alpha) coefficients for verbal and visual scales to be $r = 0.70$ and $r = 0.59$, respectively. Kirby et al. (1988) tested the validity of modified questionnaires by comparing other instruments testing verbal and visual abilities. The verbal ability is compared with ACER Higher Test, Form ML (Australian Council for Educational Research, 1981) which contains vocabulary, verbal similarities, verbal reasoning, and verbal analogy problems. The visual ability is compared with Card Rotation test and Surface Development test (Ekstrom, French, Harman, & Derman, 1976). The correlation of the verbal section of the Modified VVQ is $r = .321$, $p < .005$ (one-tailed). Although the correlation of the visual section of the modified VVQ compared with Card Rotation test is not significant, $r = .105$, $p > .05$, the Surface Development test is statistically significant, $r = .27$, $p < .005$ (one-tailed).

The study uses the difference between verbal and visual scores in the Modified VVQ as the cognitive style index number; negative numbers were used to represent the intensity of verbal cognition, positive numbers were used to represent the intensity of visual cognition.

Memory Achievement Test

The memory achievement test measured learner's ability to remember content information immediately after interacting with the treatment. The memory achievement test is an answer sheet with 20 written questions (Appendix D). The questions require simple graph drawing and memory recall. Participants are asked to write down what they learn; this is the tool for collecting participants' memory achievement. The test questions were validated by two of MIS experts (course instructors) and the reliability (alpha) coefficients for the memory achievement test was $r = 0.69$.

In order to neutralize grading bias, the answers were graded by two teaching assistants who are familiar with the content. The grading scale interval is 1 to 2 for each of the twenty questions. The final scores were decided by the two teaching assistants when scores were discrepant.

Problem Solving Test

The problem solving test consists of five open-ended questions (Appendix E). Participants were asked to apply what they learned to new situations. The test questions were also validated by two of MIS experts (course instructors) and the reliability (alpha) coefficients for the problem solving test was $r = 0.52$.

To neutralize grading bias, the answer sheets were graded by two teaching assistants who are familiar with the content. Individual grades were scored on a scale from 1 to 10 for each of the five questions. The final scores were decided by the two teaching assistants when scores were discrepant.

The memory achievement and problem solving tests were arranged as a single packet with two sections. Before the tests, the participants were asked to answer which intervention they have watched (Appendix D). This question was used to confirm that the participants have received their designated intervention.

Interview

The interview consisted of two open-ended questions that asked participants how they felt about the instructional material after completed the experiment. It was used for helping to

provide an external evidence for the statistical analysis result and to understand the reason of influencing learning performance.

Apparatus

The experiment was took place at two computer classrooms depending on their available time. The two computer classrooms possess the same seating allocation and computer configuration with sixty computers in each classroom (Figure 5). All computers were Pentium 4 CPU running Windows 2000 operating system and displaying with 17" CRT color monitor.

Participants were not allowed to control the program by themselves, because the presentation was sent by computer broadcast system. Participants then watched the presentation individually. The unitary broadcasting of the presentation assured participants would not affected by others who finished earlier. A broadcasting speaker system was used for participants to listen to the presentation's narration.

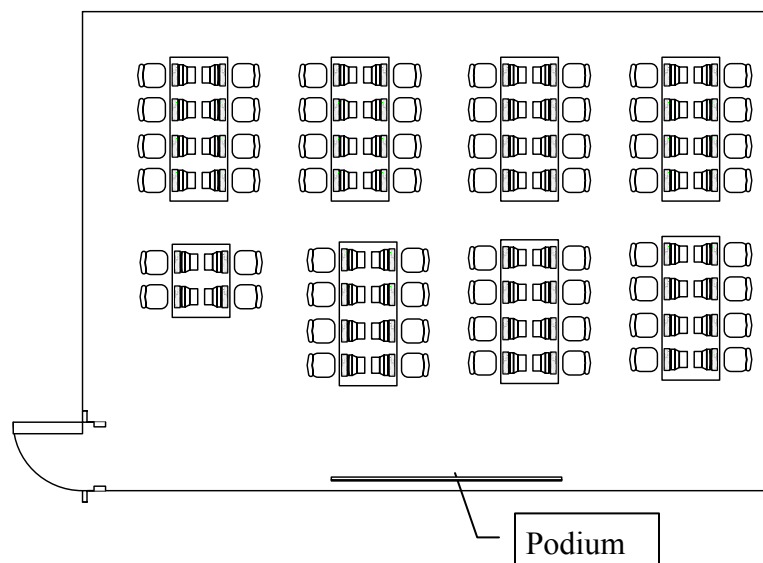


Figure 5: Computer Classroom Seating

Procedure

The experiment consisted of three phases: recruitment, instruction, and post tests. Due to limited seating in the computer classroom, participants were asked to participate on a specific day.

Recruitment Phase

- The consent form (see appendix B) was distributed and described in the class to ask students' willingness to participate the experiment. Participants were notified that any of their acts and results in the experiment would not affect their grade in the course. Only those who agree were recruited as experimental participants.
- A "Modified Verbalizer-Visualizer Questionnaire" (Appendix C) with pre-marked number was given to assess participants' self-rating of cognitive style.
- Participants were identified by numbers to protect their confidentiality. According to participants' ratings of verbal or visual processing of information, they were equally assigned to four groups to neutralize effects that may have resulted from cognitive style.
- Sixty-five 65 cases were randomly selected in each of the four groups for attending the instruction phase.

Instruction Phase

- Participants were exposed to the designated intervention. They were assigned to a designated time and computer classroom according to their learning style index.

- Each computer classroom presented one of the four intervention modules to avoid different finish time that may have affected learning achievement. There were two separated time and computer classroom for each intervention group to increase the external validity.

Post test Phase

- After the instruction, a memory achievement test was given. Participants were asked to answer simple questions or draw diagrams on the test sheet.
- A problem solving test was given after the retention test. Participants were asked to answer questions on the test sheet.
- Five participants in each group were then randomly selected and interviewed to obtain their reactions to the interventions.

Data Analysis

The study included four independent variables (simultaneous verbal redundant, simultaneous verbal non-redundant, sequential redundant text, and sequential non-redundant text presentation) and two dependant measures (memory achievement and problem solving test scores). These variables were analyzed by using Multiple Analysis of Variance (MANOVA) with SPSS 11.01.

To test the study hypotheses, the four independent variables were analyzed in two-way combinations of verbal redundancy (redundant vs. non-redundant) and presentation sequence (simultaneous vs. sequential). The interview results were also examined for response patterns to better explain the statistical findings.

Limitations of the Study

The study was limited in terms of sample, experimental content and data collection.

Limitations of the Sample

The sample for this study was limited to undergraduate college students, limiting the generalizability of findings to similar learner populations.

Limitations of Experimental Contents

The results of this study contributed to knowledge on verbal redundancy effects, replicating a prior study done by Moreno and Mayer (2002). While the present study applied different contents, including different learning objectives than the Moreno and Mayer study, the generalizability of the findings are still limited to descriptive content with animation.

Limitations of Data Collection

The study examined short-term learning outcomes of verbal redundant explanation with spatial information. The target learners were exposed to the intervention for 10 or 20 minutes, followed by an immediate post test. Thus, there may be insufficient time for the intervention to have measurable effects on learning and the evidence for learning was limited to measures of immediate recall and reasoning. Data on long term effects was not included in this study.

CHAPTER FOUR: FINDINGS

This study sought to answer two primary research questions: (a) Does redundant text improve learning performance if learners are presented with instructional material that addresses subject matter other than cause-and-effect relationship? and (b) Does sequential presentation of animation followed by redundant text help learning? Six hypotheses were tested to answer the two questions. Statistically significant differences, at 95% confidence level for the population ($p < 0.05$), were found in two interventions, resulting in the rejection of two of the six null hypotheses. The analysis also revealed significant interactions between several variables. Interviews with participants supported a number of the findings. Chapter 5 further details the results of the study. First, results specific to the primary hypotheses are presented. Second, the results of the follow up analyses examining potential interactions between the primary variables under study are described. Finally, responses to two questions provided by 20 participants interviewed five days after interacting with the interventions are summarized.

Statistical Analyses

A Box's Test (Box, 1953) was used for testing the equality of covariance matrices among the two dependent variables in the four intervention groups. The result showed the homogeneity assumption of the data was not violated. The assumptions of Analysis of Variance (ANOVA) were also tested prior to each analysis. A Levene's Test of Equality of Error Variances (Levene, 1960) indicated that the variance in both memory achievement and problem solving test scores between simultaneous redundant, simultaneous verbal non-redundant, sequential verbal

redundant, and sequential verbal non-redundant groups were homogeneous. A Multiple Analysis of Variance (MANOVA) was used for main effect and follow up analyses in memory achievement and problem solving test scores.

Primary Hypotheses Results

The statistical measures regarding the primary study hypotheses are reported in Table 5, including mean and standard deviations of memory achievement and problem solving test scores for verbal redundancy and presentation sequence. Maximum possible memory achievement test score was 40 and maximum possible problem solving test score was 50.

Table 5:
Mean and Standard Deviation for the Study Hypotheses

| Presentation | Memory Achievement | | Problem Solving | |
|-----------------------|--------------------|-----------|-----------------|-----------|
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Verbal Redundancy | | | | |
| Redundant | 22.77 | 6.96 | 14.77 | 8.53 |
| Non-redundant | 23.30 | 7.69 | 13.25 | 9.57 |
| Presentation Sequence | | | | |
| Simultaneous | 25.41* | 6.47 | 16.19* | 7.90 |
| Sequential | 20.66 | 7.38 | 11.83 | 9.67 |

Hypothesis 1

Null Hypothesis 1: There is no statistically significant difference in memory achievement test scores between redundant and non-redundant presentations.

The study results show no statistically significant difference in memory achievement test scores ($F_{1, 220} = 0.33, p = .57$) between verbal redundant and non-redundant groups (Table 5). Less than 0.2% of the variance in memory achievement test scores can be accounted for the differences between redundant and non-redundant groups. Meaning there was no memory achievement test scores difference between redundant and non-redundant text presentations when combining with animation. Note that although verbal redundancy was not statistically significant, there is a pattern showing that the simultaneous non-redundant group scored higher on memory achievement test scores than the simultaneous redundant group, and the sequential redundant group scored higher than the sequential non-redundant group in the same test scores.

Hypothesis 2

Null Hypothesis 2: There is no statistically significant difference in memory achievement test scores between simultaneous and sequential presentations.

A statistically significant difference was found in memory achievement test scores ($F_{1, 220} = 26.14, p < 0.01$) between simultaneous ($M = 25.41, SD = 6.47$) and sequential ($M = 20.66, SD = 7.38$) groups (Table 5). Nearly 11% of the variance in memory achievement test scores can be accounted for the differences between simultaneous and sequential groups. Meaning there was a memory achievement test scores difference between simultaneous and sequential presentations when combining with animation.

Hypothesis 3

Null Hypothesis 3: There is no statistically significant interaction effect in memory achievement test scores between verbal redundancy and presentation sequence.

Because prior study (Moreno & Mayer, 2002) indicates that simultaneous non-redundant text produces higher memory achievement test scores, while sequential redundant text produces higher problem solving test scores. Hypothesis was to test the interaction effect of the previous study results.

There was no statistically significant interaction ($F_{1, 220} = 0.92, p = 0.34$) in memory achievement test scores between verbal redundancy and presentation sequence. Less than .4% of the variance in memory achievement can be accounted for the differences between verbal redundancy and presentation sequence.

Although interaction between simultaneous and sequential presentation was significant, the interaction effects of presentation sequence revealed a statistically significant group interaction between the simultaneous and sequential groups ($F_{1, 220} = 26.14, p < 0.01$). Nearly 11% of the variance in the study's population can be explained by the differences between simultaneous and sequential groups in terms of memory achievement test scores. The simultaneous non-redundant group ($M = 26.13, SD = 6.4$) was significantly different from the sequential redundant group ($M = 20.84, SD = 5.9$) and the sequential non-redundant group ($M = 20.48, SD = 7.9$), but not different from the simultaneous redundant group ($M = 24.7, SD = 6.53$).

The mean and standard deviations of memory achievement and problem solving test scores for the four intervention groups are reported in Table 6. The four intervention groups were: (a) animation, narration, and on-screen text (ANT), which represents the simultaneous redundant group; (b) simultaneous presentation of animation and narration (AN), which represents the simultaneous non-redundant group; (c) sequential presentation of animation followed by narration and on-screen text (A-NT), which represents the sequential redundant group; and (d)

sequential presentation of animation followed by narration (A-N), which represents the sequential non-redundant group.

Table 6:
Mean and Standard Deviation of Memory Achievement and Problem Solving Test Scores for Presentation Groups

| Intervention Group | Memory Achievement | | Problem Solving | |
|---------------------|--------------------|-----------|-----------------|-----------|
| | <i>M</i> | <i>SD</i> | <i>M</i> | <i>SD</i> |
| Simultaneous | | | | |
| Redundant (ANT) | 24.70* | 6.53 | 15.79* | 6.90 |
| Non-redundant (AN) | 26.13* | 6.40 | 16.59* | 8.84 |
| Sequential | | | | |
| Redundant (A-NT) | 20.84 | 6.90 | 13.75* | 9.86 |
| Non-redundant (A-N) | 20.48 | 7.90 | 9.91 | 9.18 |

Hypothesis 4

Null Hypothesis 4: There is no statistically significant difference in problem solving test scores between redundant and non-redundant presentations.

The study results show no statistical significance difference in problem solving test scores ($F_{1, 220} = 1.68, p = 0.17$) between verbal redundant and non-redundant groups (Table 5). Less than 0.8% of variance in the problem solving test scores can be accounted for the differences between redundant and non-redundant groups. Meaning there was no problem solving test scores difference between redundant and non-redundant text presentations when combining with animation.

Hypothesis 5

Null Hypothesis 5: There is no statistically significant difference in problem solving test scores between simultaneous and sequential presentation groups.

A statistically significant difference was found in problem solving test scores ($F_{1, 220} = 13.85, p < 0.01$) between simultaneous ($M = 16.19, SD = 7.9$) and sequential ($M = 11.83, SD = 9.67$) groups (Table 5). Nearly 6% of the variance in problem solving test scores can be accounted for the differences between simultaneous and sequential groups. Meaning there was a problem solving test scores difference between simultaneous and sequential presentations when combining with animation.

Hypothesis 6

Null Hypothesis 6: There is no statistically significant interaction effect in problem solving test scores between verbal redundancy and presentation sequence.

There was a significant interactions were found in problem solving test scores ($F_{1, 220} = 3.93, p < 0.05$) between verbal redundancy and presentation sequence groups. Nearly 2% of the variance in problem solving test scores can be accounted for the differences between verbal redundancy and presentation sequence. When in sequential condition, verbal redundant score was higher than non-redundant score. When in simultaneous condition, scores were higher but verbal non-redundant group and verbal redundant group were with close scores (Figure 6).

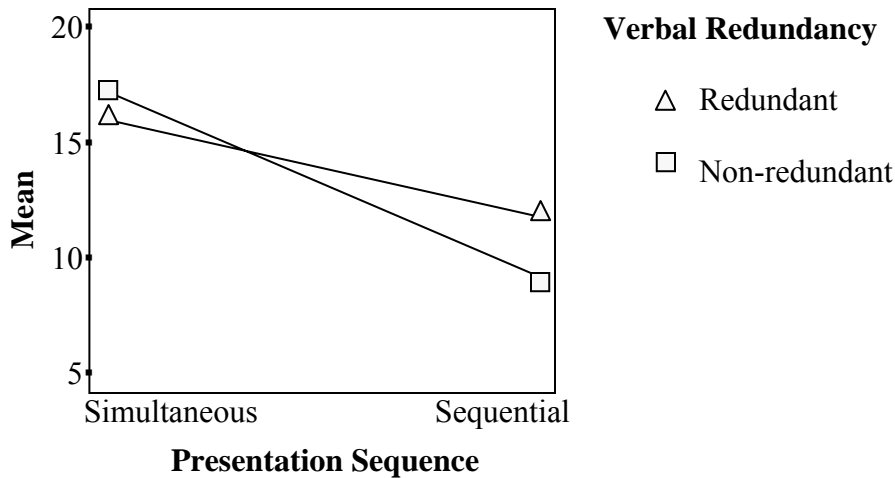


Figure 6: Interaction Effects of Presentation Sequence and Verbal Redundancy in Problem Solving Test Scores

Examination of presentation sequence effects, which compared of simultaneous and sequential presentations, revealed a statistically significant ($F_{1, 220} = 13.85, p < 0.01$) interaction in problem solving test scores between simultaneous and sequential groups (Table 6). Nearly 6% of the variance in the study's population can be explained by the differences between simultaneous and sequential groups in terms of problem solving test scores. Table 6 shows the simultaneous redundant group ($M = 15.79, SD = 6.9$) and the simultaneous non-redundant group ($M = 16.59, SD = 8.84$) are significantly different from the sequential non-redundant group ($M = 9.91, SD = 9.18$), but no statistically significant interaction between the sequential redundant group ($M = 13.75, SD = 9.86$) and the sequential non-redundant group.

Although the simultaneous redundant group is not significantly different from the sequential redundant group, the sequential redundant group shows a larger mean difference of

3.84 than the sequential non-redundant group in terms of problem solving test scores even though the two were not statistically significant.

A general outcome in mean for memory achievement and problem solving test scores is presented in Figure 7. The potential range of scores was 0 to 40 for the memory achievement test and 0 to 50 for the problem solving test. Over all, there is a large difference in total mean between memory achievement ($M = 23.04, SD = 7.32$) and problem solving test scores ($M = 14.01, SD = 9.08$). However, there is a similar pattern between memory achievement and problem test scores. Participants who received simultaneous presentations performed higher on both memory achievement and problem solving tests than those who received sequential presentations.

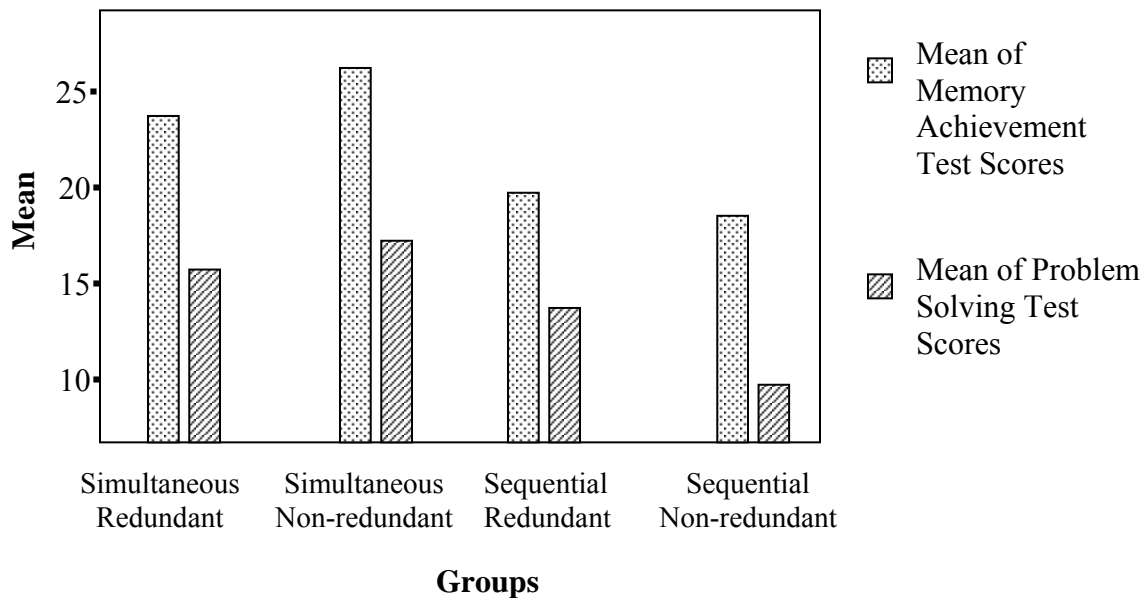


Figure 7: Summary of Memory Achievement and Problem Solving Test Scores

Follow Up Analysis

Follow up analysis extends the study hypotheses by examining the effects of redundant text in terms of Modified VVQ index numbers among the four intervention groups. There are two sub-sections: Modified VVQ index distribution of the study's sample and the relationship between learning performance and Modified VVQ index. The two sub-sections are presented addressing the purpose of the method and the analysis results.

Modified VVQ Index Distribution of the Study's Sample

Table 7 presents participants on the Modified VVQ index numbers for understanding participants' cognitive style of the study. Because a stratified sampling method was used, the distribution patterns of Modified VVQ index numbers were generally similar across four groups. Most participants tended to learn using visual cognition. The majority fell between 0 (neither verbal nor visual) and 6 (visual intensity) in the Modified VVQ index. Overall, more than 84% of the participants fell between 0 and 6 intensity of visual cognition.

Table 7:
Modified VVQ Index Numbers Distribution of the Four Treatment Groups

| Modified VVQ Index | Simultaneous | | Sequential | | Total N (%) |
|--------------------|--------------|-----------------|-------------|-----------------|-------------|
| | Redundant N | Non-redundant N | Redundant N | Non-redundant N | |
| -2 | . | . | 1 | 2 | 3 (1.2) |
| -1 | 4 | 2 | 1 | 4 | 12 (5.1) |
| 0 | 5 | 6 | 6 | 4 | 21 (9.0) |
| 1 | 5 | 5 | 5 | 7 | 23 (9.9) |
| 2 | 4 | 6 | 11 | 4 | 26 (11.1) |
| 3 | 15 | 14 | 9 | 12 | 50 (21.5) |
| 4 | 7 | 7 | 9 | 9 | 34 (14.6) |
| 5 | 4 | 6 | 8 | 7 | 25 (10.7) |
| 6 | 6 | 5 | 1 | 5 | 17 (7.3) |
| 7 | 4 | 4 | 4 | 1 | 13 (5.6) |
| 8 | 2 | . | 1 | . | 3 (1.3) |
| 9 | . | 1 | . | . | 1 (0.4) |
| 10 | . | . | . | 1 | 1 (0.4) |
| Total | 56 | 56 | 56 | 56 | 224 (100) |

Relationship between Learning Performance and Modified VVQ Index

Both memory achievement and problem solving test scores were examined with Modified VVQ index numbers to understand the relationship between cognitive style and learning performance. The study considered learning performance as a combination of memory achievement and problem solving test outcomes. The mean and standard deviation of memory achievement test scores listed by Modified VVQ index numbers are displayed in Table 8. There was no statistically significant difference in memory achievement test scores among different

Modified VVQ index numbers. No obvious pattern is found across the Modified VVQ index numbers in terms of memory achievement test scores.

Table 8:
Mean and Standard Deviation for Memory Achievement Test Scores in Each Modified VVQ Index Numbers

| Modified VVQ Index | Simultaneous | | Sequential | |
|--------------------|---------------------------|-------------------------------|---------------------------|-------------------------------|
| | Redundant <i>M(SD)</i> | Non-redundant <i>M(SD)</i> | Redundant <i>M(SD)</i> | Non-redundant <i>M(SD)</i> |
| -2 | . | . | 10.00 (.) | 25.50 (2.12) |
| -1 | 20.00 (4.08) | 29.00 (5.66) | 17.00 (.) | 19.75 (6.70) |
| 0 | 31.20 (7.40) | 28.00 (4.56) | 22.67 (4.08) | 25.50 (1.29) |
| 1 | 25.60 (5.86) | 24.60 (8.88) | 21.60 (4.39) | 20.29 (4.23) |
| 2 | 23.50 (3.11) | 29.00 (4.90) | 18.64 (4.11) | 21.50 (9.68) |
| 3 | 23.87 (6.25) | 26.00 (7.03) | 22.22 (10.26) | 17.25 (7.21) |
| 4 | 25.86 (7.76) | 24.00 (9.26) | 20.11 (3.66) | 22.56 (7.14) |
| 5 | 25.25 (4.19) | 25.33 (5.13) | 18.88 (7.99) | 17.86 (12.82) |
| 6 | 23.50 (9.09) | 25.80 (6.14) | 19.00 (.) | 24.20 (10.18) |
| 7 | 23.25 (6.40) | 24.25 (5.06) | 28.50 (11.03) | 19.00 (.) |
| 8 | 25.50 (7.78) | . | 26.00 (.) | . |
| 9 | 30.00 (.) | . | . | . |
| 10 | . | . | . | 12.00 (.) |

The mean and standard deviation of problem solving test scores listed by Modified VVQ index numbers are displayed in Table 9. There was no statistically significant difference in problem solving test scores among different Modified VVQ index numbers. No obvious pattern is found across the Modified VVQ index numbers in terms of problem solving test scores.

Table 9:
Mean and Standard Deviation for Problem Solving Test Scores in Each Modified
VVQ Index Numbers

| Modified VVQ Index | Simultaneous | | Sequential | |
|--------------------------|---------------------------|-----------------------------------|---------------------------|-----------------------------------|
| | Redundant <i>M(SD)</i> | Non- redundant <i>M(SD)</i> | Redundant <i>M(SD)</i> | Non- redundant <i>M(SD)</i> |
| -2 | . | . | 10.00 (.) | 14.50 (19.09) |
| -1 | 22.75 (7.93) | 15.00 (1.41) | 6.00 (.) | 11.25 (9.22) |
| 0 | 16.80 (8.26) | 22.33 (13.57) | 13.50 (13.41) | 14.75 (11.53) |
| 1 | 18.20 (3.27) | 8.60 (7.83) | 20.40 (13.05) | 11.57 (6.85) |
| 2 | 13.00 (4.40) | 22.33 (7.84) | 14.09 (8.95) | 10.25 (9.57) |
| 3 | 14.73 (8.63) | 18.86 (10.08) | 16.33 (10.47) | 6.00 (6.58) |
| 4 | 12.29 (6.02) | 12.57 (7.35) | 10.22 (7.12) | 7.56 (9.37) |
| 5 | 15.25 (8.22) | 15.00 (3.46) | 14.13 (11.15) | 11.29 (11.06) |
| 6 | 18.00 (5.83) | 17.20 (3.96) | 1.00 (.) | 10.40 (10.33) |
| 7 | 14.75 (1.26) | 12.50 (2.52) | 13.00 (7.44) | 3.00 (.) |
| 8 | 15.50 (4.95) | . | 11.00 (.) | . |
| 9 | . | 10.00 (.) | . | . |
| 10 | . | . | . | 26.00 (.) |

Interview Results

To help explain the statistical results and to better understand the effects of verbal redundancy and presentation sequence on learning performance, five participants from each of the four groups were randomly selected and asked if they would respond to a couple interview questions after completing of the intervention. The interviewees were asked two questions: “What do you think after you watching the multimedia instructional material Understanding Data Flow Diagram?” and “What’s your suggestion for improving this instructional material?”

The study-related interview results provide additional evidence to explain the statistical findings. Two interviewees in the simultaneous redundant group mentioned they had difficulty

watching animation and text at the same time. Two interviewees in the simultaneous non-redundant group stated that providing supplemental text would help them better understand the content information. Four interviewees in the sequential redundant group noted difficulty in watching disjointed animation and text. All five interviewees in the sequential non-redundant group also mentioned difficulty in watching disjointed animation and narration.

Some answers were not directly related to the primary research questions. However, those answers indicated the individual learning preferences or problems of the intervention content; it may also affected learning performance and thus interfered with the study results. Participants' responses to the question regarding the instructional material included pace problems, unclear pronunciation of narration, difficult to understand, and too much information in the content. Participants' responses to the question regarding improvement included requested learner control, color indication, more examples, and more vivid animations (Table 10).

Table 10:
Interviewees Responses from the Four Treatment Groups

| | Simultaneous | | Sequential | |
|---|--------------|-------------------|------------|-------------------|
| | Redundant | Non- redundant | Redundant | Non- redundant |
| | N | N | N | N |
| <u>Question 1:</u> | | | | |
| Hard to keep pace with animation & text | 2 | | | |
| Disturbed with animation then text | | | 4 | |
| Difficult with animation then narration | | | | 5 |
| Pace too fast | 1 | 1 | 2 | 3 |
| Unclear the narration | | | 1 | |
| Difficult to understand | 1 | 1 | | 1 |
| Too much information in the content | 1 | | 1 | |
| <u>Question 2:</u> | | | | |
| Need supplemental text | | 2 | | 2 |
| Need learner control | 1 | 2 | 1 | 2 |
| Need color indication | | | 1 | |
| Need more vivid animations | | | | 1 |
| Need more examples | | 1 | 1 | 1 |

CHAPTER FIVE: DISCUSSION AND CONCLUSIONS

Chapter 5 discusses the results of the study presented in chapter 4 in light of prior research. Potential answers to the two primary research questions are discussed in terms of results obtained from testing the research hypotheses. The interview results are also discussed to support the findings as well as to explore potential reasons why some of the hypotheses were not supported. In the conclusion section, research implications, limitations, and opportunities for future research are discussed.

Question 1: Verbal Redundancy Effects

The first research question asked whether redundant text improves learning performance if learners are presented with instructional material that addresses subject matter that does not focus on cause-and-effect relationships. Because the conclusion that verbal redundant explanation impairs learning when presented with additional visual information is based on experiments with cause-and-effect content information (Moreno & Mayer, 2002), other subject matter may generate different results. The effects of verbal redundancy were examined by measuring learning performance between students who received redundant text and non-redundant text presentations. To answer the first research question, the effects of verbal redundancy (identical narration and on-screen text versus narration only in both simultaneous and sequential presentations) were examined to determine its influence on learning performance. Interactions between four groups in terms of memory achievement and problem solving test scores, along with interview responses were also examined to further describe the results.

Discussion regarding research question one includes consistent results, inconsistent results, and a summary answer to the question.

Results Consistent with Literatures

The results do not show significant difference in verbal redundancy in memory achievement and problem solving scores. In other words, there was no difference in both memory achievement and problem solving test scores between participants who received redundant text (animation with narration and on-screen text and animation followed by narration and on-screen text) and non-redundant text (animation with narration and animation followed by narration). Both findings are consistent with prior redundant text studies that also yielded no significant differences in achievement when participants were presented with redundant text and non-redundant text presentations (e.g., Moreno & Mayer, 2002). Because participants in the two redundant and the two non-redundant groups earned both high and low scores, they cancelled each other out. For example, the higher scores earned by participants in the simultaneous non-redundant group were neutralized by the lower scores earned by participants in the sequential non-redundant group when the two groups were combined to establish scores for non-redundant presentations.

Results Inconsistent with Literatures

Some results regarding verbal redundancy did not agree with Moreno and Mayer's (2002) findings. The results of this study showed no significant difference between redundant and non-redundant groups who received either simultaneous or sequential presentations, whereas the effects of redundant and non-redundant presentations on either learner's memory achievement or

problem solving test scores were significantly different in Moreno and Mayer's study. However, similar with Moreno and Mayer's study, results revealed no statistical significance between redundant and non-redundant presentations. The interview with participants helps explain why significant differences between verbal redundant and non-redundant groups were not found. In the simultaneous non-redundant group, two out of five interviewees said they needed text assistance to help understand when receiving animation and narration presentations. Whereas in the simultaneous verbal redundant group, two out of five interviewees expressed the presentation was too fast to comprehend graphics and words when receiving animation and on-screen text at the same time.

A possible reason for the inconsistency with previous results may be that the instructional content was too difficult to comprehend when given the chance to watch only once. In the interview, several participants across the four groups indicated the intervention pace was too fast to grasp the contents. Many interviewees also requested learner control to stop and review the content during the instructional time.

Another possible reason was that over half of the population of the participants tend to learn by visual cognition as suggested by the Modified VVQ results, meaning they may omit on-screen text when learning with simultaneous redundant presentation. They may also be accustomed to having television and movie subtitles in their lives, which is why they may not be distracted from the on-screen text when watching simultaneous redundant materials.

Summary Answer to Question 1

The first research question investigated the effects of redundant text in multimedia environments. The results suggest redundant text does not always impair learning when

accompanied with animation. In addition, various learners' characteristics may lead to different learning outcomes. For example, the participant's learning preference and previous learning experiences may affect the effects of using redundant text on learners' achievement.

Question 2: Presentation Sequence Effects

The second research question examined whether sequential presentation of animation followed by redundant text helps learning. Prior studies suggest that dual-processing by using both vision and hearing helps learning (Lewandowski & Kobus, 1989, 1993). Thus, sequential presentation of animation, followed by redundant verbal explanations, may eliminate split-attention, and retain the advantages of dual-processing learning (Moreno & Mayer, 2002). To answer the second question, the effects of presentation sequence (simultaneous versus sequential presentations), were examined to understand the influence on learning performance. The interactions between verbal redundancy and presentation sequence, along with interview responses are also discussed to extend the results. Discussion regarding second research question includes consistent results, inconsistent results, and a summary answer to the question.

Results Consistent with Literature

In this study, participants who received simultaneous presentations scored higher in both memory achievement and problem solving tests, than participants who received sequential presentations. In other words, participants who received both simultaneous presentations of animation, narration, and on-screen text, and animation and narration scored higher on measures of learning performance than participants who received sequential presentations of animation followed by narration, and on-screen text and animation followed by narration. The study results

are consistent with past research on the contiguity principle for multimedia learning (Mayer & Anderson, 1991). The principle holds that different modes of information need to be contiguously presented to facilitate learning. Sequential presentation of animation and verbal explanation may break the message connection between vision and hearing and thus causing lower learning performance.

Results Inconsistent with Literature

Some results regarding presentation sequence did not agree with Moreno and Mayer's (2002) study. The simultaneous redundant group generated significantly higher memory achievement test scores than the sequential redundant group, which contradicts Moreno and Mayer's study.

The study results also showed that participants in the sequential redundant group did not earn significantly higher problem solving test scores than the two simultaneous groups, which is again inconsistent with Moreno and Mayer (2002). Furthermore, the study yielded results contradictory to Moreno and Mayer in that participants in the simultaneous sequential redundant group scored significantly higher on the problem solving test than participants in the sequential non-redundant group. Moreno and Mayer indicated that sequential redundant presentation helps generate conceptual solutions on problem solving tests, rather than simultaneous presentations; a result that is not supported by the present study. Interviews with participants in the two sequential presentation groups help explain why low learning performance occurred. Three out of five interviewees in the sequential redundant group and all five interviewees in the sequential non-redundant group mentioned the difficulty of receiving animation and verbal explanation separately. Participants also mentioned difficulties with the content. They stated that it was hard

to keep pace with the instruction and indicated that giving only one opportunity to watch the instruction may not be suitable for learning the contents. Participants may have put most of their effort on memorization instead of reasoning. Low problem solving test scores in the study supports the inference.

A possible explanation for the inconsistency in results, between this study and Moreno and Mayer's study, is that the learning descriptive content is highly dependent on the reference between animation and verbal explanation. Because special symbols in this study's instructional content represent specific meaning and rules by themselves, sequentially presenting animation followed by verbal explanation may break the referential connections between the two types of information and generate higher cognitive load, thus leading to lower scores in the two sequential presentation groups.

Summary Answer to Question 2

The second research question investigated the effects of sequential presentation in multimedia environments. The study results suggest sequential presentations may lead to lower learning performance when animation and verbal explanation are closely related. For example, describing the use of rules alone with animation for a Data Flow Diagram symbol requires immediate cognitive interaction between verbal explanation and animation. The separation of the two types of information may break the immediate connections between them, thus lowering learning performance.

Cognitive Style and Learning Performance

Although investigating the relationship between cognitive style and learning performance was not the focus of this study, it provides another perspective in understanding the effects of different modality on learner performance. The memory achievement and problem solving test scores in the four groups did not show distinct patterns between different Modified VVQ index numbers. Such results suggest that cognitive style was not related to different presentations of animation and verbal explanation in terms of achievement scores. However, few participants were verbal learners in the present study; the results can only hold that there is no learning performance difference among neutral and verbal learners.

Conclusions

The study reexamined the effects of redundant text on learners' memory achievement and problem solving ability, when accompanied with animations. The study replicated an investigation by Moreno and Mayer (2002) and extended research on cognitive load theory by utilizing different conditions. Overall, the study results support previous research on the contiguity principle for multimedia presentations. Consistent with conclusions reported by Mayer and Anderson (1991, 1992), the sequential presentation of visual information followed by verbal explanation was found to impair learning.

On the other hand, the study does not fully support previous research on verbal redundancy (Kalyuga et al., 2004; Leahy et al., 2003; Moreno & Mayer; 2002) because various conditions, including characteristics of learners and characteristics of the contents, led to different results. Simultaneous redundant text explanation may not be a factor for influencing

learning performance, a learner with long-term exposure to complicated electronic messages may not so much affect achievement when receiving redundant instructional presentation. Meanwhile, content with descriptive knowledge may be another factor for lowering learning performance when separately presenting visual and verbal information.

Several inferences and suggestions according to the study findings are described in the research implications, limitations, and recommendations for future research sections.

Research Implications

The previous redundant text studies hold that simultaneous presentation of redundant text and spatial information impairs learning when cause-and-effect content is presented (Kalyuga et al., 2004; Moreno & Mayer, 2002), whereas the present study suggests that learning performance may not be affected as much by redundant text with descriptive content as it is affected by cause-and-effect content. Furthermore, learners' previous learning experiences may also contribute to the inconsistent results. Redundant verbal messages may not result in cognitive overload if learners get used to watching narration and on-screen text, which means different learning situations may influence the result.

In addition, the descriptive content used in this study requires considerable memory, reasoning, and application to perform well on the memory achievement and problem solving tests. Because the instructional content is new to the students, they may not be able to fully understand if watched only once. Memorization and assimilation of the new information may greatly influence cognition, and thus, the effects of redundant text may be limited when presented with descriptive content.

Although the findings do not strongly support previous studies on redundant text in multimedia learning (Kalyuga et al., 2004; Leahy et al., 2003; Moreno & Mayer, 2002), the pattern of results is mostly consistent with the idea that redundant text results in lower learning performance when simultaneously presented with other visual information. The cause of split-attention was also found in the interview results; some participants mentioned attending too much information when receiving animation, narration, and on-screen text at the same time. This is due to the competition between on-screen text and other spatial information which splits learners' attention and thus causes high cognitive load (Kalyuga et al., 1999; Leahy et al., 2003; Tindall-Ford et al., 1997).

The sequential presentations reveal lower learning performance in both memory achievement and problem solving test scores, which is inconsistent with Moreno and Mayer's (2002) study that suggests redundant text helps creative thinking when presented with sequential presentation. Sequential presentations eliminate split-attention influences from animation and on-screen text and thus simultaneously presenting redundant text helps understanding (Moreno & Mayer, 2002). However, breaking the referential connections between animation and verbal explanation may also lead to lower learning performance (Mayer & Anderson, 1991, 1992; Moreno and Mayer, 2002). The symbols introduced in the study's instructional content were strongly related to meanings and rules, which is the reason sequential presentations may be the cause for lower scores in both memory achievement and problem solving test scores. The study results suggest cognitive load may be influenced by different modes of presentation which is consistent with studies by Mayer and Anderson (1991, 1992). Various presentation conditions can influence cognitive load even when redundant text is presented to learners.

Limitations

The study has five limitations. First, students completed the experiment between late November and mid time of December. During this time, students were finishing midterm examination, and were looking forward to holidays. In other words, they did not want additional instruction and testing. This was a time of decreased class attendance. It is unknown how this inattentive behavior may have affected students focus on learning the material, but students could be expected to be more unorganized in learning than the normal time frame.

Second, problem solving ability test scores were, on average, very low. The means of problem solving test scores were: $M = 15.79$ for the simultaneous redundant group, $M = 16.59$ for the simultaneous non-redundant group, $M = 13.75$ for the sequential redundant group, and $M = 9.91$ for the sequential non-redundant group. The possible scores for problem solving test are lowest 0 and highest 50. Low test scores bring into question the practical validity of the intervention, and thus, the significance of the results. Although the results indicated that simultaneous verbal redundant and simultaneous verbal non-redundant scored significantly higher on the problem solving test than sequential verbal non-redundant, if the intervention was not effective in developing learners problem solving ability, the practical validity of the intervention and related methods for reducing cognitive load are questionable, limiting the generalizability of the reported findings.

Third, the low reliability of the problem solving test brings into question the validity of test results. If the problem-solving test is not reliable, then the possibility of a Type I error (finding significant differences when there really are no significant differences), as well as Type

II error (finding insignificant results when there actually may be significant differences) increases, again limiting the conclusions and generalizability of the results.

Forth, descriptive content requires student to rely heavily on both memory and reasoning. A number of participants indicated pace was too fast, difficult to understand, and need more control over the instructional content. Because participants were only allowed to watch the instructional contents once, they may not have had sufficient time to comprehend the instruction. Therefore, the results may not truly reflect the actual impact modality may have had on the participants' learning performance.

Fifth, the fact that participants are accustomed to having television and movie subtitles in their lives is a somewhat unique situation in Taiwan; they may develop their own cognitive means to cope with such situation. The participants may not have been affected by redundant text and animation compared to those who are not use to having subtitles in their lives. As a result, the study conclusions are limited to participants in countries where movie subtitles are common.

Recommendation for Future Research

The study's results reveal a need for additional research using various conditions for presenting redundant text in multimedia environments. The results suggest that the effects of redundant text may be influenced by a number of conditional factors. For example, the instructional content used in this study relies heavily on the connection between animation and on-screen text. The use of content information that does not have such high contiguity requirements may lead to different results. Another issue that should be addressed in future research is the practical validity of the instructional materials. Implementation of the intervention should result in a range of test scores, including some that demonstrates mastery of the specified

learning objectives. Formative evaluation of the instructional material, including both expert reviews and student participation in one-to-one, small group and pilot test, are particularly important if time is held constant in future experiments, to ensure the practical validity of the intervention. Presentation sequence is another conditional factor worthy of further research. Reversing the order by presenting text followed by animation may lead to different results because text information may provide a foundation for understanding animation. Finally, the effects of learners' prior media experiences on cognitive load should be explored in further detail. The results suggest that cognitive load may be reduced if learners have enough prior experience watching animation, narration, and on-screen text simultaneously.

There is a need for investigations using various conditions to determine a suitable means of using redundant text presentations across situations. Additional research is needed to explore the factors that may influence this relationship. Further research in these areas would contribute to the advancement of designing multimedia instructional materials.

APPENDIX A:

IRB LETTER



Office of Research & Commercialization

November 15, 2005

Shiau-Lung (Robert) Chu
1741 Demetree Drive
Winter Park, FL 32789

Dear Mr. Chu:

With reference to your protocol #05-3071 entitled, **Investigating the Effectiveness of Redundant Text and Animation in Multimedia Learning Environments,** I am enclosing for your records the approved, expedited document of the UCFIRB Form you had submitted to our office. **This study was approved on 11/13/05. The expiration date will be 11/12/06.** Should there be a need to extend this study, a Continuing Review form must be submitted to the IRB Office for review by the Chairman or full IRB at least one month prior to the expiration date. This is the responsibility of the investigator. **Please notify the IRB office when you have completed this research study.**

Please be advised that this approval is given for one year. Should there be any addendums or administrative changes to the already approved protocol, they must also be submitted to the Board through use of the Addendum/Modification Request form. Changes should not be initiated until written IRB approval is received. Adverse events should be reported to the IRB as they occur.

Should you have any questions, please do not hesitate to call me at 407-823-2901.

Please accept our best wishes for the success of your endeavors.

Cordially,

A handwritten signature in cursive script that reads "Barbara Ward".

Barbara Ward, CIM
UCF IRB Coordinator
(FWA00000351, IRB00001138)

Copies: IRB File
Atsusi Hirumi, Ph.D.

BW:jm

APPENDIX B:
EXPERIMENT PARTICIPATION CONSENT

Letter of Consent

Dear Student:

I would like to invite your participation in my study related to gathering information on how learning performance is affected by various configurations of multimedia presentation. This research project is part of my doctoral studies.

I would like you to answer a questionnaire regarding your learning style, watch a 20-minute multimedia instruction, and then followed by memory achievement and problem solving tests. Some of you will be randomly selected for asking feedback about the learning material.

Your identity will be kept confidential for research purpose only. Your participation in this project is voluntary. You do not have to answer any question(s) that you do not wish to answer. Please be advised that you may choose not to participate in this research, and you may withdraw from the experiment at any time without consequence. Non-participation will not affect your grade. There are no other direct benefits or compensation for participation. There are no anticipated risks associated with participation.

If you have any question about this research, please contact Shiau-Lung (Robert) Chu at (xx)xxxx-xxxx; or his faculty supervisor, Dr. Atsusi Hirumi, College of Education, Orlando, FL; (xxx)xxx-xxxx. Questions or concerns about research participants' rights may be directed to the UCFIRB office, University of Central Florida Office of Research, Orlando Tech Center, 12443 Research Parkway, Suite 207, Orlando, FL 32826. The Phone number is (407)823-2901.

Sincerely,

Shiau-Lung (Robert) Chu
Ph. D. Candidate
University of Central Florida
E-mail: robertchutw@gmail.com

- I have read the procedure describe above.
- I voluntarily agree to participate in the procedure and I have received a copy of this description.
- I am age of 18 years or older.

_____/_____
Signature Date

實驗參與意願書

各位同學好：

在此我想邀請你們參與我的研究，這是研究關於使用不同媒體組合對於學習所造成的影響。這份研究是為了完成我在中佛羅里達大學的博士論文。

你將參與的活動包括回答一份有關學習方式的問卷、觀看一個約 20 分鐘的多媒體教材、及之後進行的記憶測驗和問題解決測驗。

你的資料將保密僅供研究者分析，不會對其它人公開。你的參與是自願的。你是否參與這個研究並不會對你的成績造成任何影響。你可以拒絕要回答任何不想回答的問題。你可以不參與，並且有權力在任何時候拒絕參與這個研究。這個研究不會對你有任何危險。

如果你對我的研究有任何疑問，請打電話給我。我的電話是 (xx)xxx-xxx。我的指導老師是 Dr. Atsusi Hirumi, College of Education, Orlando, FL; 電話是 (xxx)xxx-xxxx。如果對於你參加的權力有任何疑問，請詢問 UCFIRB Office, University of Central Florida Office of Research, Orlando Tech Center, 12443 Research Parkway, Suite 207, Orlando, FL 32826. 電話是 (407)823-2901。

謝謝你的參與

朱孝龍
博士候選人
美國中佛羅里達大學
E-mail: robertchutw@gmail.com

- 我讀了以上的說明。
- 我願意參與這項研究，並且我取得了這份說明書副本。
- 我已經十八歲或超過十八歲。

簽名

日期

APPENDIX C:
KIRBY, MOORE, AND SCHOFIELD'S (1988) MODIFIED 20-ITEM
VERSION OF RICHARDSON'S VERBALIZER-VISUALIZER
QUESTIONNAIRE (VVQ)

Verbal items

1. I enjoy doing work that requires the use of words.
我喜歡用文字方式來表達的事
2. I enjoy learning new words.
我喜歡學新的字詞
3. I can easily think of synonyms for words.
我看到一個字時，可以很容易想到它的同義字
4. I read rather slowly.
我的閱讀速度很慢
5. I prefer to read instructions about how to do something rather than have something show me.
我不喜歡讓別人做給我看，寧可自己閱讀手冊或說明書
6. I have better than average fluency in using words.
我比一般人更能流利地使用語文
7. I spend little time attempting to increase my vocabulary.
我很少花時間去增強認識新的詞彙
8. I dislike word games like crossword puzzles.
我不喜歡玩填字遊戲
9. I dislike looking words up in dictionaries.
我不喜歡查字典
10. I have a hard time remembering the words to songs.
記歌詞對我來說很困難

Visual items

11. I don't believe that anyone can think in terms of material pictures.
我不相信任何人會用圖形來思考問題
12. I find illustrations or diagrams help me when I'm reading.
我覺得插圖或圖表可以幫助我閱讀
13. I have a hard time making a "mental picture" of a place that I've only been to a few times.
要我回想只去過幾次的地方是什麼樣子，是很困難的事
14. I seldom use diagrams to explain things.
我很少用圖表的方式來表達事情
15. I like newspaper articles that have graph.
我喜歡報紙中有圖片的文章
16. I don't like maps or diagrams in books.
我不喜歡書中的地圖或圖表
17. When I read books with maps in them, I refer to the maps a lot.
當我閱讀有附地圖的書時，會經常參照著地圖一起看
18. The old saying "A pictures is worth a thousand words" is certainly true for me.
我認同 "一張圖片勝過許多文字" 這種說法
19. I have always disliked jigsaw puzzles.
我一向不愛拼圖遊戲
20. I find maps helpful in finding my way around a new city.
在陌生城市中找路時，我覺得地圖很有用

APPENDIX D:
MEMORY ACHIEVEMENT TEST



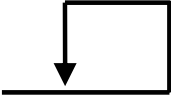
Thank you for watching the instruction

Please mark on which type of instruction material “Understanding Data Flow Diagram” you have watched?

- Animation, narration, and on-screen text
- Animation and narration
- Animation followed by narration and on-screen text
- Animation followed by narration

MEMORIZATION QUESTIONS


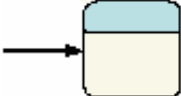
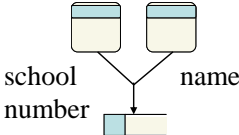
Recall what you have watched and provide your **brief answer or drawing** in the column below “Your Answer.” Here are some examples:

| No. | Question | Your Answer |
|-----|---|---|
| 01 | What is the name of this symbol?  | <i>Data Flow</i> |
| 02 | Please draw a symbol for a “Data Flow.” |  |
| 03 | Explain this according to the DFD rules.  | <i>A data flow cannot go directly to itself</i> |

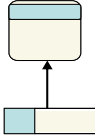
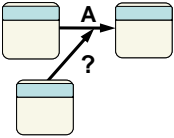
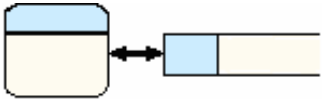
Please start to answer questions on next page

(More on next page)

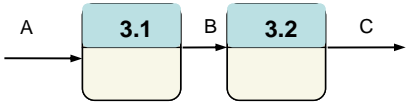
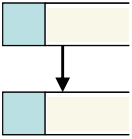
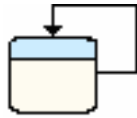
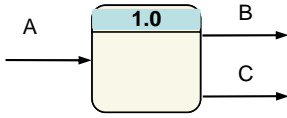
Please answer the 20 brief questions, you have 15 minutes to complete.

| No. | Question | Suggested Answer |
|-----|---|------------------|
| 1 | What is the name of this symbol?  | |
| 2 | Please draw a symbol for an “Entity.” | |
| 3 | Explain this according to the DFD rules.  | |
| 4 | What is the function of the symbol “Entity?” | |
| 5 | Explain this according to the DFD rules.  | |
| 6 | What is the function of the symbol “Process?” | |
| 7 | Please draw a symbol for a “Data Store.” | |

(More on next page)

| No. | Question | Your Answer |
|-----|---|-------------|
| 8 | What is the function of the symbol “Data Flow?” | |
| 9 | Is it true that an arrow can represents many kinds of data as long as it is processed together? | |
| 10 | Explain this according to the DFD rules.  | |
| 11 | What should the question mark be?  | |
| 12 | Please draw a simple diagram using data flows to connect data store, entity, and process. | |
| 13 | Please draw a simple diagram showing data flow passing through data store to another data store. | |
| 14 | Please draw the correct diagram.  | |

(More on next page)

| No. | Question | Suggested Answer |
|-----|--|------------------|
| 15 | Please draw the level 0 diagram  | |
| 16 | What is the major concern of balancing DFD? | |
| 17 | Explain this according to the DFD rules.  | |
| 18 | Please draw a simple diagram showing data flow passing through entity to data store. | |
| 19 | Please draw the correct diagram.  | |
| 20 | Please draw a balanced level 1 diagram.  | |



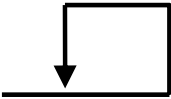
謝謝你觀看本多媒體教材

你所觀看的多媒體教學教材 “認識資料流程圖” 是（請勾選你看的是哪一種？）：

- 同時播放動畫、旁白、及字幕。
- 同時播放動畫及旁白。
- 先播放動畫，再播放旁白及字幕。
- 先播放動畫，再播放旁白。

簡答題

請回想你所看過的內容，將簡要答案或繪圖寫在“答案欄”內，以下是幾個例子：

| No. | 問題欄 | 答案欄 |
|-----|--|---|
| 01 | 這個符號的名稱是什麼？  | 資料流 |
| 02 | 請繪製一個“資料流”(Data Flow)符號。 |  |
| 03 | 以 DFD 規則辨別是否有誤並說明原因  | 資料流不可直接傳回給自己 |

請翻下一頁開始回答測驗題

(請見後頁)

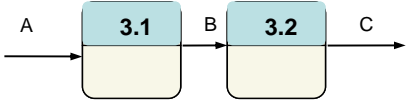
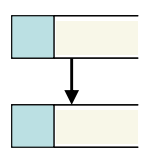
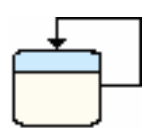
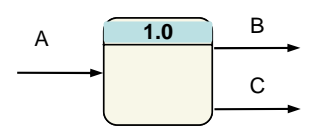
請簡要回答下列 20 題：

| No. | 問題欄 | 回答欄 |
|-----|--|-----|
| 1 | 這個符號的名稱是什麼？  | |
| 2 | 請繪製一個 “外部實體” (Entity) 符號 | |
| 3 | 以 DFD 規則辨別是否有誤並說明原因  | |
| 4 | “外部實體” (Entity) 的功用是什麼？ | |
| 5 | 以 DFD 規則辨別是否有誤並說明原因  | |
| 6 | 請說明 “程序” (Process) 的功用。 | |
| 7 | 請繪製一個 “資料儲存” (Data Store) 符號。 | |

(請見後頁)

| No. | 問題欄 | 回答欄 |
|-----|--|-----|
| 8 | “資料流” (Data Flow)符號的功用是什麼？ | |
| 9 | “資料流” (Data Flow)的資料只要整合在同一組，無論多少種資料都可以用一個箭頭來表示。對或錯？ | |
| 10 | 以 DFD 規則辨別是否有誤並說明原因  | |
| 11 | 這個問號應該填入什麼？  | |
| 12 | 請畫一個簡圖包含“資料流” (Data flow)連接“資料儲存” (Data store), “外部實體” (Entity) 及“程序” (Process) | |
| 13 | 請繪製一個從"資料儲存" (Data Store)到另一個"資料儲存" (Data Store) 的 DFD 圖。 | |
| 14 | 以 DFD 規則辨別是否有誤並說明原因  | |

(請見後頁)

| No. | 問題欄 | 回答欄 |
|-----|--|-----|
| 15 | 請畫出這個圖的第 0 層圖 (Level 0) <div style="text-align: center; margin: 10px 0;">  </div> | |
| 16 | 什麼是平衡 DFD 圖？請說明應該注意什麼。 | |
| 17 | 以 DFD 規則辨別是否有誤並說明原因 <div style="text-align: center; margin: 10px 0;">  </div> | |
| 18 | 請繪製一個從 "外部實體" (Entity) 流入到 "資料儲存" (Data Store) 的 DFD 圖。 | |
| 19 | 請畫出正確的圖 <div style="text-align: center; margin: 10px 0;">  </div> | |
| 20 | 請畫出這個圖的 Level 1 (注意平衡)。 <div style="text-align: center; margin: 10px 0;">  </div> | |

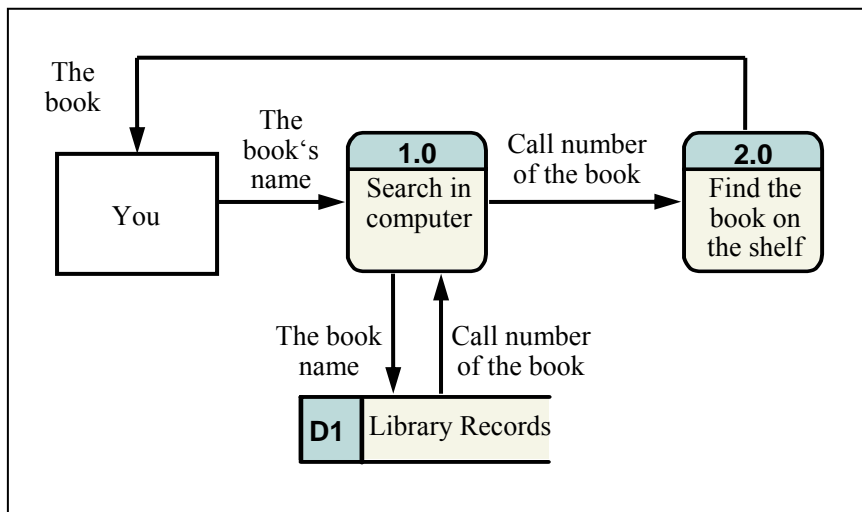
APPENDIX E:
PROBLEM SOLVING TEST

SCENARIO QUESTIONS

Please carefully read the statement or DFD below, then draw a suitable DFD or explain the situation on an answer sheet. You have 20 minutes to complete 5 questions.

Scenario 1: *Find a Book*

You need to find a book in a library. Here are your procedures in the DFD. Please write the steps about how you found the book based on the DFD below:



Scenario 2: *Check a Friend's Address*

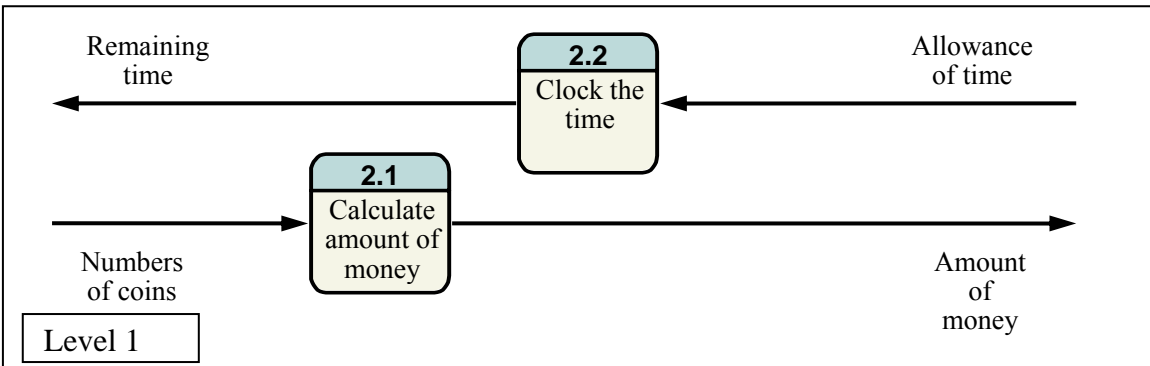
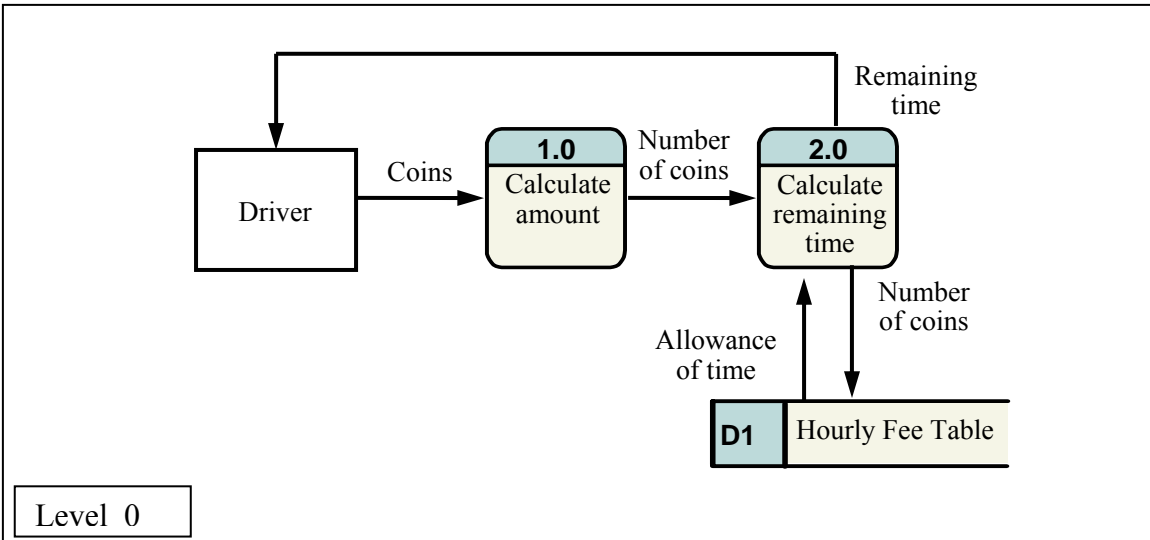
One day, your and a friend talked about a friend of yours, Adam. Your friend was wondering whether you have Adam's address. Please draw a DFD showing how you find out Adam's address based on the statement below:

- Your friend asked the name "Adam."
- You get name "Adam" and then recall the full name.
- Use the full name to locate Adam's associate address in the address book and then tell your friend.

(More on next page)

Scenario 3: *The Parking Meter*

This is a simple work process of parking meter. Please write the steps of how parking meter works based on the DFD below:



Scenario 4: *The Point-of-Sales System*

Here is a point-of-sale system for checking out with credit cards in a gift store. Please draw a DFD based on the steps describing how it works below:

- (a) Customer takes the gift to the counter.
- (b) The item number is obtained and then sent to the items record to retrieve the item price.
- (c) The customer pays with credit card, a transaction data included credit card information and item price is sent to the bank for obtaining the confirmation number. The detailed payment processes are:
 - (c1) The credit card information and the item price are gathered as transaction data and then sent to the bank.
 - (c2) The bank approves with sending back a conformation number; the system prints out a receipt when the confirmation number is received.
- (d) A receipt is given to the customer when the transaction is completed.

Scenario 5: *The Package Delivery System*

The XYZ Company intends to improve their package delivery system. They need a DFD showing the present logical process. Please help them to develop a DFD by reading the statements below:

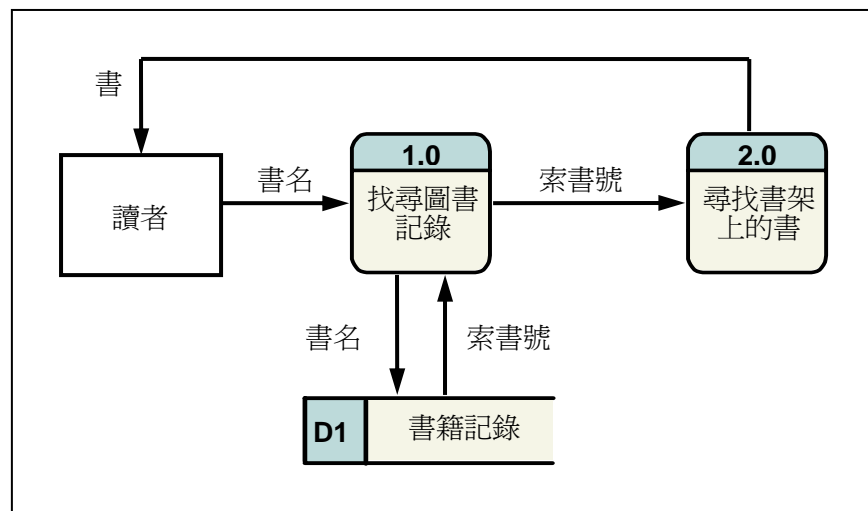
A tracking number will be created when counters receives a package. The tracking number and delivery address will be updated as tracking data. The update process includes (1) editing the tracking number and delivery address as new tracking data; (2) verifying the updated tracking data that retrieved from the tracking record. Revised tracking data will be sent to re-edit if data is incorrect. The new tracking data is sent for storage in the tracking record and returned with updated tracking data. If the verification is correct, the tracking data will be sent for controlling delivery. The controlled delivery process will issue a delivery notice; this data will be returned if package is delivered and then send a delivered notice will be sent to the customer.

案例分析

請仔細閱讀下列案例說明，根據題目要求在答案紙上繪製 DFD 圖或解釋說明。

案例一：找一本書

下圖是一般讀者在圖書館找尋圖書的流程。請根據這個 DFD 圖寫出如何找到書的步驟（請以條列方式回答，可參考案例二）。



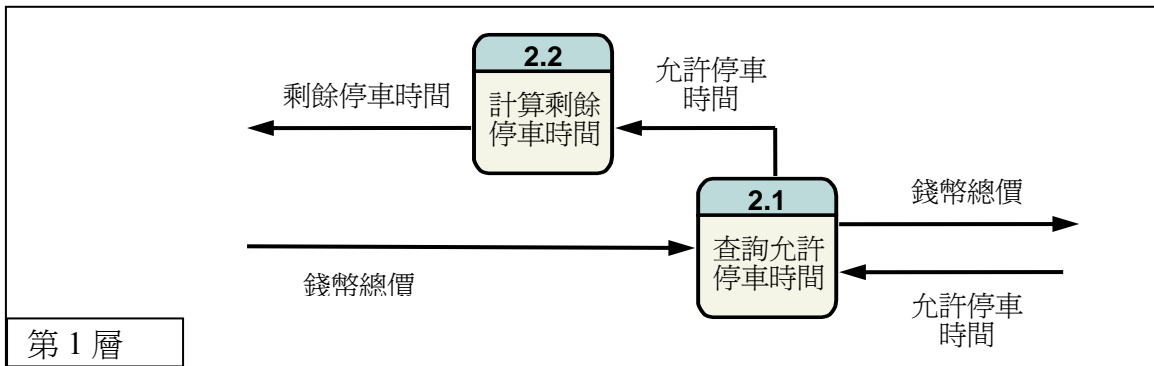
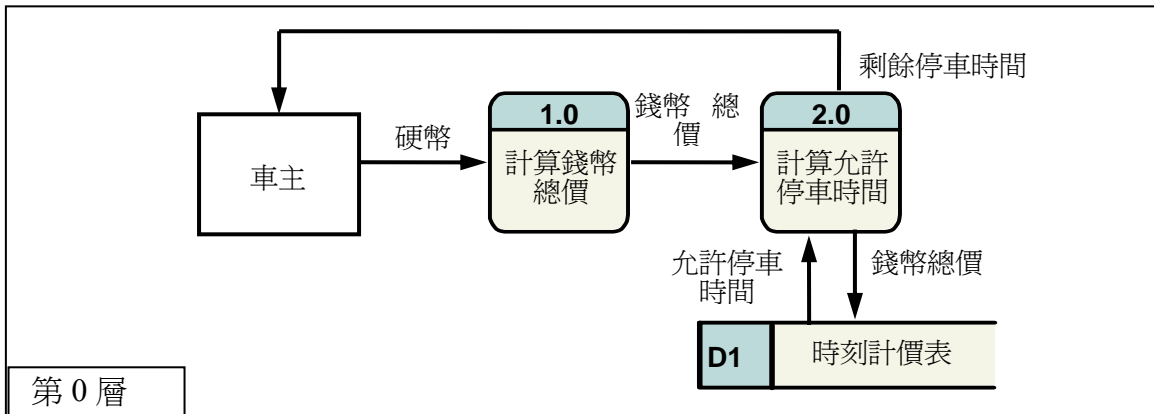
案例二：查詢朋友地址

有天你與朋友提到另一個朋友-小亞，你的朋友問你有沒有小亞的地址。請畫一個 DFD 圖表示你是如何根據下列敘述找到小亞的地址：（繪圖方式可參考案例一）

- 你的朋友用 { “小亞” } 這個綽號詢問地址。
- [1.0] 回憶 “小亞” 姓名：你聽到 “小亞” 就開始回憶 { “小亞” 的姓名 }。
- [2.0] 找尋對應地址：用 { “小亞” 的姓名 } 在 [D1] 地址簿 中找尋相對應 { “小亞” 的地址 }，找到後告訴你朋友 { “小亞” 的地址 }。

案例三：停車計費器

這是個停車計費器的簡單工作流程。請根據下圖（第0層及第1層）寫出停車器費器工作步驟：（請以條列方式回答，可參考案例四）



案例四：POS 端點銷售系統

禮品店以端點銷售系統 (Point-of-sale System) 用來處理信用卡結帳事宜。請根據下列敘述的工作步驟畫一個 DFD 圖：

- (a) 顧客把欲結帳的{禮品}拿到櫃臺。
- (b) [1.0]取得貨品號碼：從{禮品}上取得貨品號碼，以該{貨品號碼}從 [D1]貨品紀錄檔中查得{貨品價格}。
- (c) [2.0]處理付款：獲得顧客{信用卡資料}，將信用卡資料及[1.0]傳過來的{貨品價格}整合成{轉帳資料}傳送給銀行，銀行傳回{准許號碼}，將{收據}交給顧客。詳細的處理付款步驟在第 1 層中表示：
 - (c1) [2.1]整合卡號及價格：將{信用卡資料}及{貨品價格}整合成為轉帳資料，並將{轉帳資料}傳送給銀行。
 - (c2) [2.2]印出收據：系統收到銀行傳回的{准許號碼}並印出{收據}。

案例五：包裹快遞系統

愛克公司希望能加強他們包裹快遞系統。他們需要一個 DFD 圖顯示目前的邏輯程序。請根據下列敘述，幫他們繪製一個 DFD 圖：

當櫃臺收到包裹，會產生一個「追蹤碼」，並同時和寄送地址一起送出給「追蹤碼管理」。「追蹤碼管理」負責送出「新追蹤資料」給「追蹤記錄檔」儲存資料，「追蹤記錄檔」並負責傳回「追蹤資料」給「追蹤碼管理」。「追蹤碼管理」同時傳送「追蹤資料」給「遞送管理」。「追蹤碼管理」的詳細步驟包括：

- (1) 將「追蹤碼」及「寄送地址」送入「編輯追蹤碼」，編輯後送出新追蹤資料。
- (2) 「管控追蹤資料」從「追蹤記錄檔」取出「追蹤資料」排序控制送出「追蹤資料」給「遞送管理」處理。

「追蹤資料」會被送出供「遞送管理」負責管控。「遞送管理」會發出一個「遞送通知」給「目的地」。如果包裹已送達，「已送達資料」會被傳回「遞送管理」，「遞送管理」傳送「送達通知」給原交寄的「顧客」。

APPENDIX F:
INTERVIEW QUESTIONS

Interview Questions

1. What do you think after you watching the multimedia instructional material “Understanding Data Flow Diagram?”

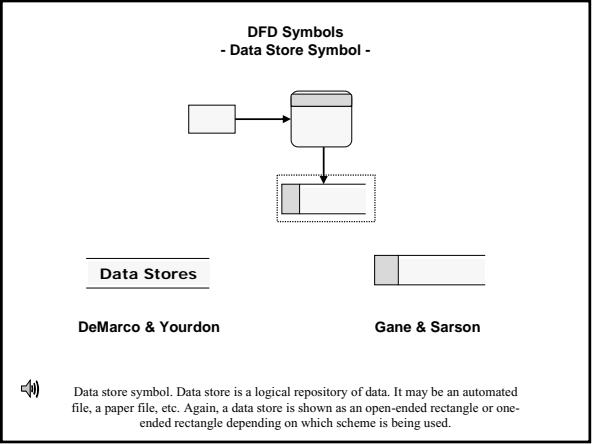
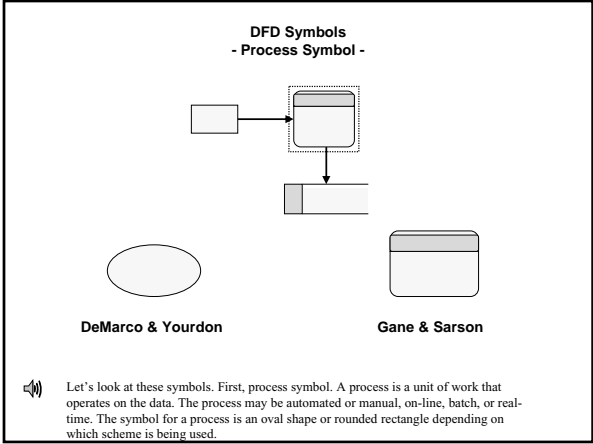
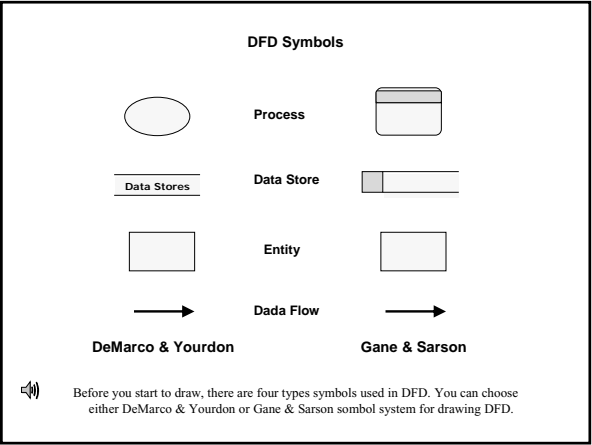
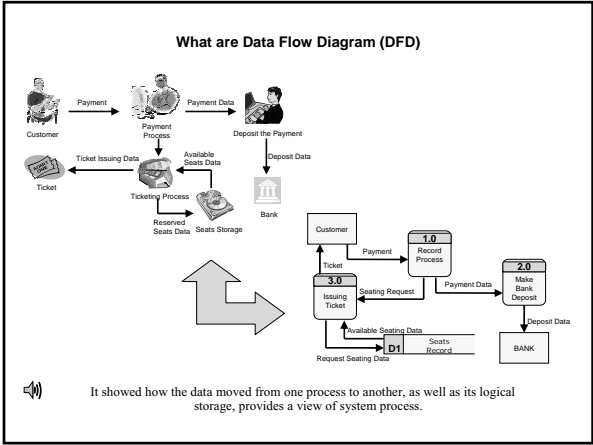
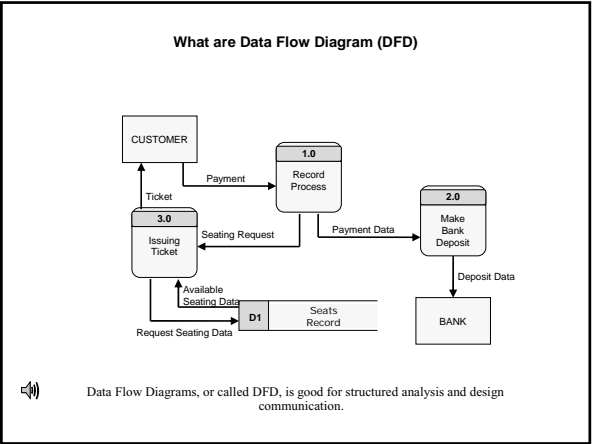
看過多媒體教材 “認識資料流程圖”，你認為如何？

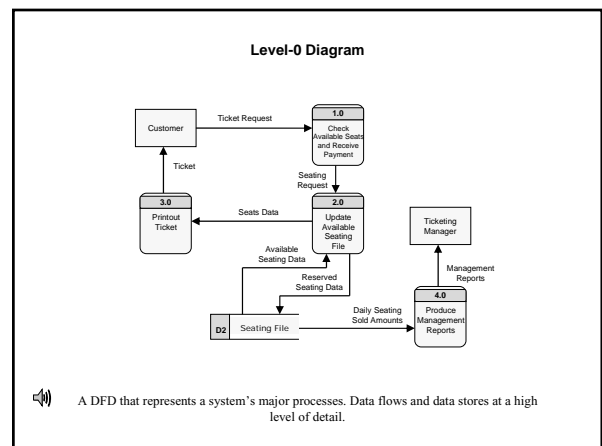
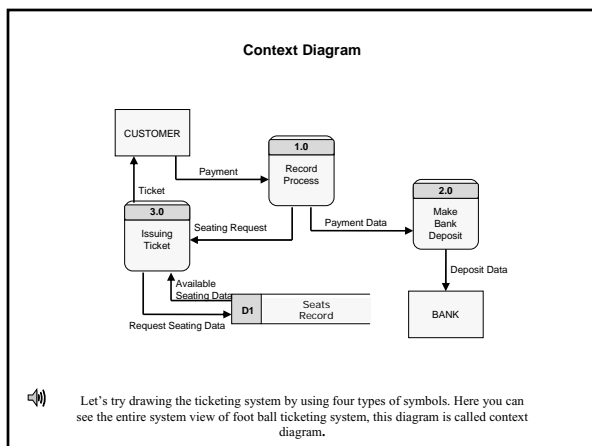
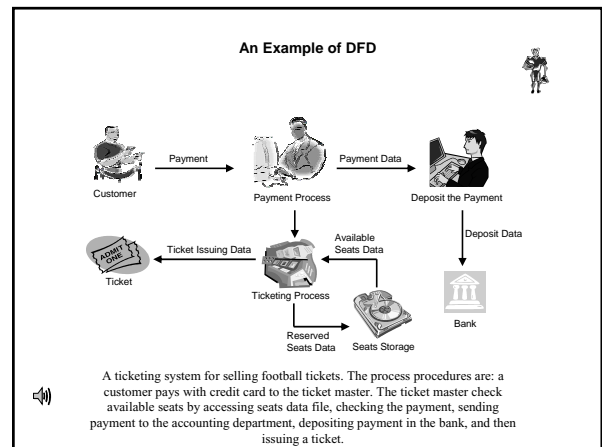
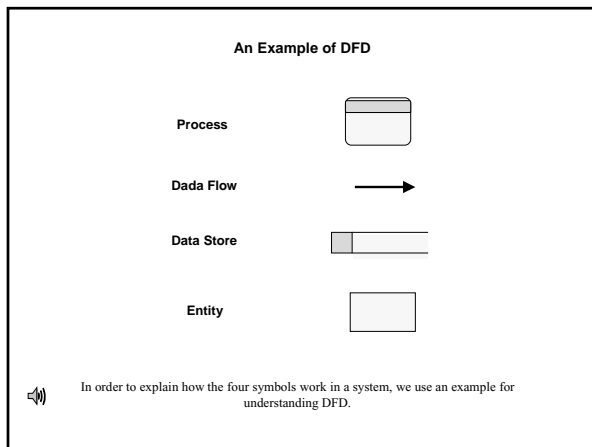
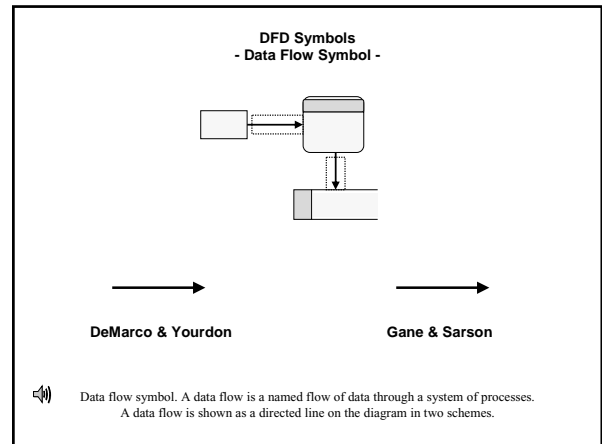
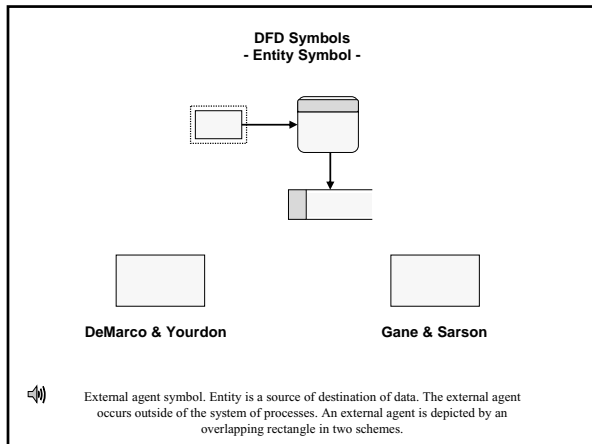
2. What’s your suggestion for improving this instructional material?

你建議如何改進這個教材？

APPENDIX G:
**MULTIMEDIA INSTRUCTIONAL MATERIAL “UNDERSTANDING
DATA FLOW DIAGRAM”**

Understanding Data Flow Diagram





Data flow diagramming rules

There are several rules you must follow when drawing DFDs.

**Data flow diagramming rules
- Process -**

Incorrect **correct**

No process can have only outputs. It is making data from nothing. If an object has only outputs, then it must be a source.

**Data flow diagramming rules
- Process -**

Incorrect **correct**

No process can have only inputs. If an object has only inputs, then it must be a sink.

**Data flow diagramming rules
- Process -**

Incorrect **correct**

A process has a verb phrase label.

**Data flow diagramming rules
- Data Store -**

Incorrect **correct**

Data cannot move directly from one data store to another data store. Data must be moved by a process.

**Data flow diagramming rules
- Data Store -**

Incorrect **correct**

Data cannot move directly from an outside source to a data store. Data must be moved by a process which receives data from the source and places the data into the data store.

**Data flow diagramming rules
- Data Store -**

Incorrect **correct**

🔊 Data cannot move directly to an outside sink from a data store. Data must be moved by a process.

**Data flow diagramming rules
- Data Store -**

Incorrect **correct**

🔊 A data store has a noun phrase label.

**Data flow diagramming rules
- Entity -**

Incorrect **correct**

🔊 Data cannot move directly from a source to an entity. It must be moved by a process if the data are of any concern to our system. Otherwise, the data flow is not shown on the DFD.

**Data flow diagramming rules
- Entity -**

Incorrect **correct**

🔊 A entity has a noun phrase label.

**Data flow diagramming rules
- Data Flow -**

Incorrect **correct**

🔊 A data flow has only one direction of flow between symbols. It may flow in both directions between a process and a data store to show a read before an update. The latter is usually indicated, however, by two separate arrows since these happen at different times.

**Data flow diagramming rules
- Data Flow -**

Incorrect **correct**

🔊 A fork in a data flow means that exactly the same data goes from a common location to two or more different processes, data stores, or entity (this usually indicates different copies of the same data going to different locations).

Data flow diagramming rules
- Data Flow -

Incorrect **correct**

🔊 A join in a data flow means that exactly the same data comes from any of two more different processes, data stores, or entity to a common location.

Data flow diagramming rules
- Data Flow -

Incorrect **correct**

🔊 A data flow cannot go directly back to the same process it leaves. There must be at least one other process which handles the data flow, produces some other data flow, and returns the original data flow to the beginning process.

Data flow diagramming rules
- Data Flow -

Incorrect **correct**

🔊 A data flow to a data store means update (delete or change).

Data flow diagramming rules
- Data Flow -

Incorrect **correct**

🔊 A data flow from a data store means retrieve or use.

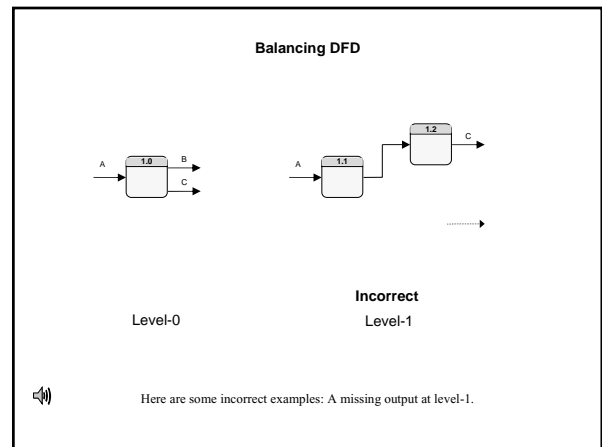
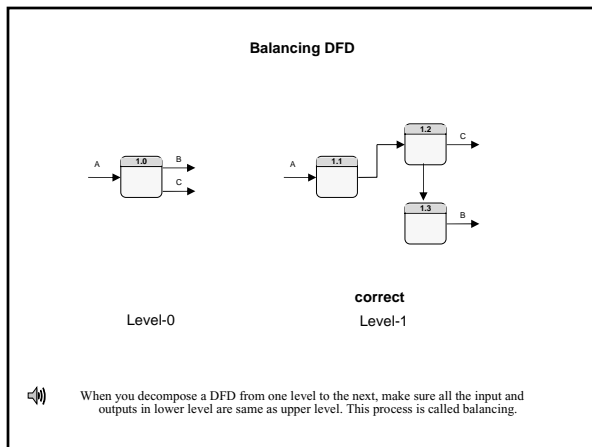
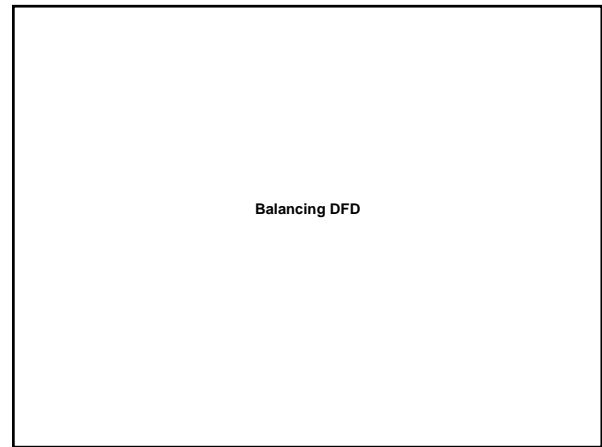
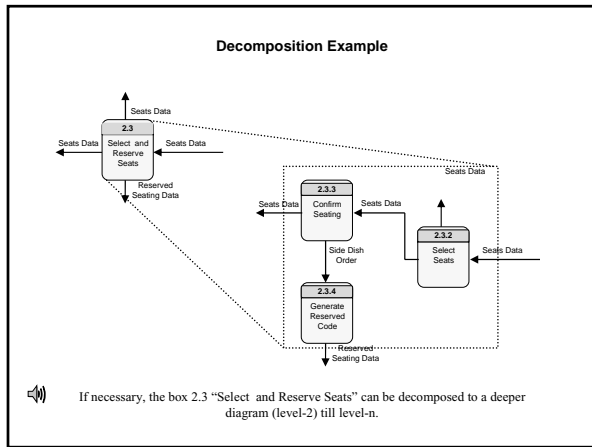
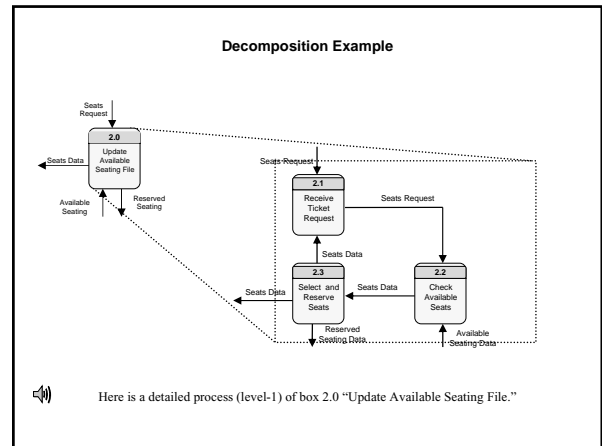
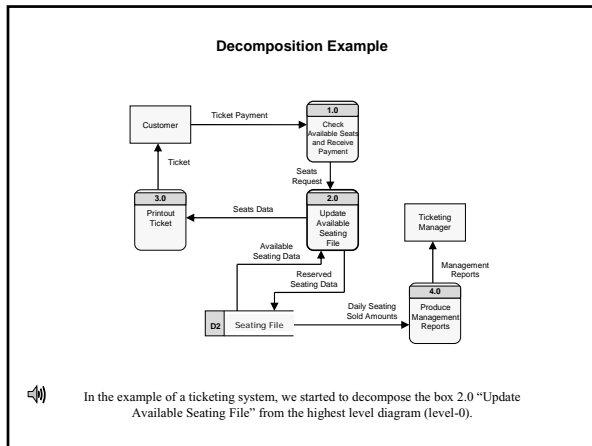
Data flow diagramming rules
- Data Flow -

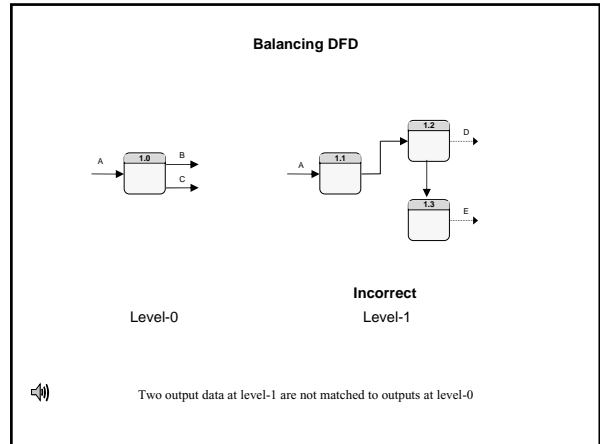
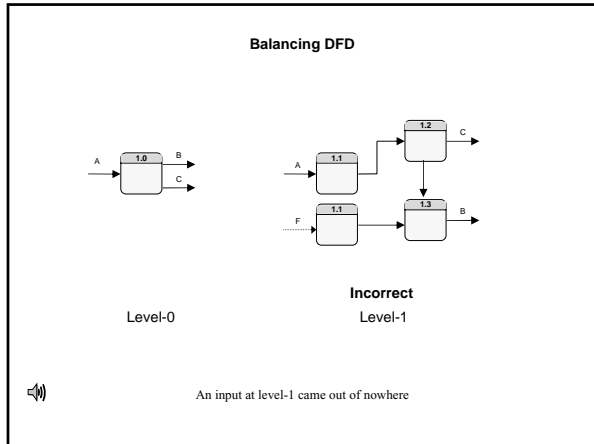
Incorrect **correct**

🔊 A data flow has a noun phrase label. More than one data flow noun phrase can appear on a single arrow as long as all of the flows on the same arrow move together as one package.

Decomposition of DFDs

🔊 The act of going from a single system to detailed component processes is called functional decomposition. It is an iterative process of breaking the description or perspective of a system down into finer and finer detail.





End of the Multimedia Program
Please **DO NOT** Refer to this Program while Answering Questions

認識資料流程圖 Understanding Data Flow Diagram

什麼是資料流程圖 (DFD)

資料流程圖 (Data Flow Diagram), 簡稱DFD, 是用來作為系統分析及系統設計的一種工具。

What are Data Flow Diagram (DFD)

資料流程圖可以顯示出資料是如何在系統中被傳遞、處理、及儲存。因此DFD是一種結構化分析圖，用來表達系統作業與資料流間的關係。

DFD Symbols

| | | |
|--|-------------------------|--|
| | 程序(Process) | |
| | 資料流(Data Flow) | |
| | 資料儲存(Data Store) | |
| | 外部實體(Entity) | |

DeMarco & Yourdon Gane & Sarson

DFD圖使用的符號可分為DeMarco & Yourdon或者Gane & Sarson兩種體系。這四種符號分別為程序(Process), 資料流(Data Flow), 資料儲存(Data Store), 和外部實體 (Entity)。

DFD Symbols - Process Symbol -

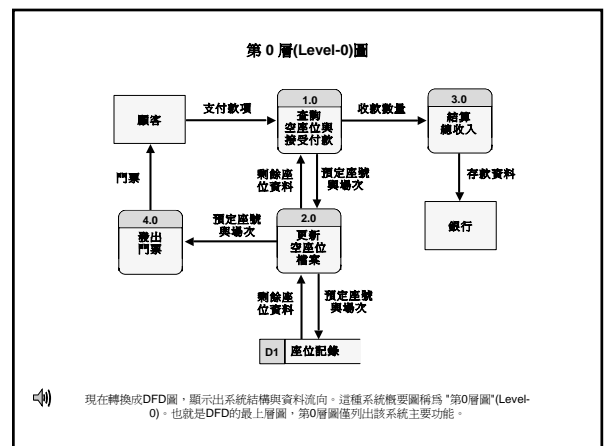
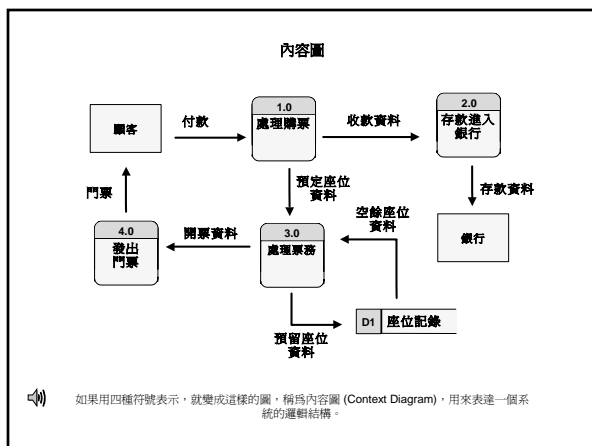
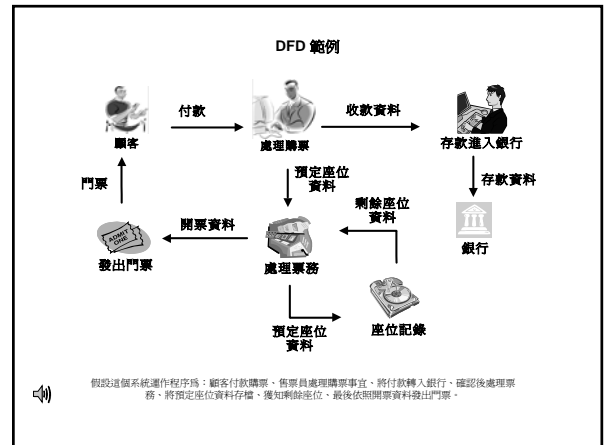
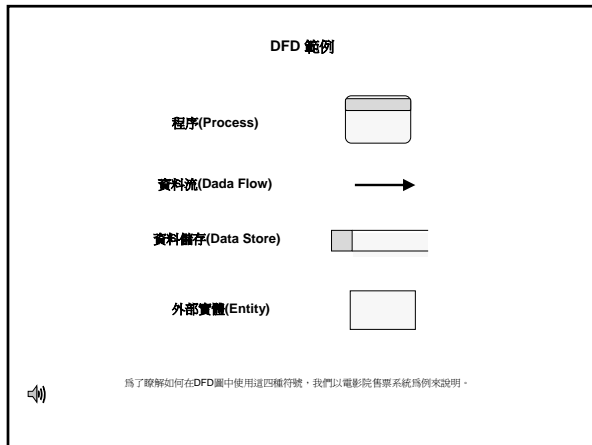
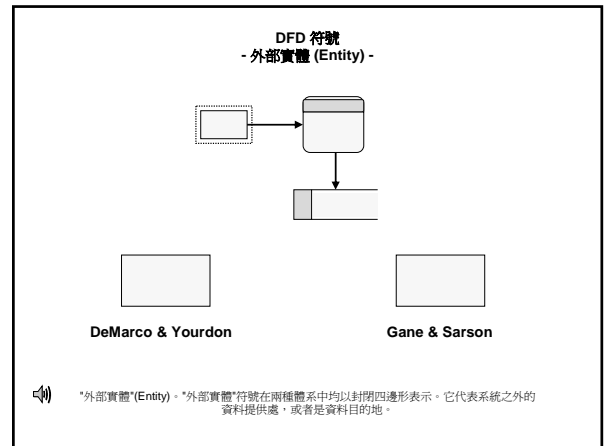
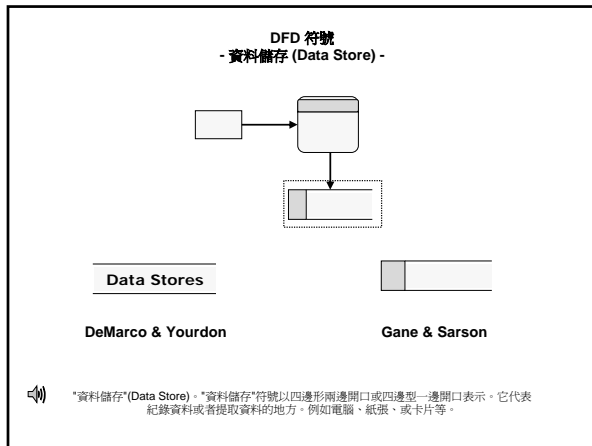
DeMarco & Yourdon Gane & Sarson

"程序" (Process)。"程序" 符號以橢圓形狀或圓角四邊形表示。代表系統中處理資料的某個步驟或者功能。

DFD Symbols - Data Flow Symbol -

DeMarco & Yourdon Gane & Sarson

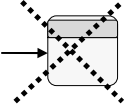
"資料流" (Data Flow)。“資料流”符號在兩個符號體系中均以箭頭表示，代表資料在系統中的流向。



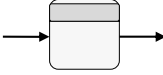
DFD圖符號使用規則

在資料流程圖中使用這四種符號時，必須要注意一些使用規則。

DFD圖符號使用規則
- 程序 (Process) 部分 -



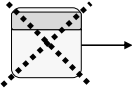
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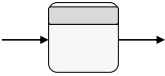
正確

*程序(Process)符號不可以只有輸入沒有輸出。如果只有輸入，那就變成"外部實體" (Entity)。

DFD圖符號使用規則
- 程序 (Process) 部分 -



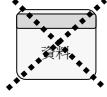
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正確

*程序(Process)符號也不可以只有輸出沒有輸入。如果只有輸出，那還仍然是外部實體 (Entity)。

DFD圖符號使用規則
- 程序 (Process) 部分 -



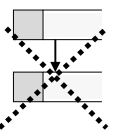
錯



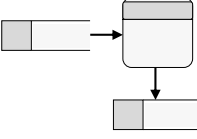
正確

*程序(Process)符號要用動詞來表示處理功能。

DFD圖符號使用規則
- 資料儲存 (Data Store) 部分 -



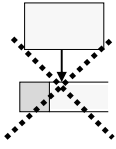
錯



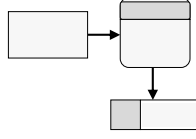
正確

使用"資料儲存(Data Store)符號時，要注意不能從一個"資料儲存"直接到另一個"資料儲存"，中間必須要經由"程序"處理過資料，才能進入"資料儲存"。

DFD圖符號使用規則
- 資料儲存 (Data Store) 部分 -



錯



正確

資料不能從"外部實體(Entity)直接進入"資料儲存(Data Store)。必須中間經過一個"程序"(Process)，資料才能被接受並儲存。

DFD圖符號使用規則
- 資料儲存 (Data Store) 部分 -

錯 **正確**

🔊 同樣的，資料不能從“資料儲存(Data Store)”直接進入外部實體(Entity)，必須中間經過一個“程序(Process)”，資料才能被送出。

DFD圖符號使用規則
- 資料儲存 (Data Store) 部分 -

錯 **正確**

🔊 “資料處理”(Data Store)使用名詞來表示它的資料類型。

DFD圖符號使用規則
- 外部實體 (Entity) 部分 -

錯 **正確**

🔊 資料不能從“外部實體(Entity)”的來源直接進入“外部實體”的目的地。中間必須經由“程序”處理資料。如果沒有經過該系統處理的需要，則不該出現在DFD圖中。

DFD圖符號使用規則
- 外部實體 (Entity) 部分 -

錯 **正確**

🔊 “外部實體”(Entity) 使用名詞來表示它的資料類型。

DFD圖符號使用規則
- 資料流 (Data Flow) 部分 -

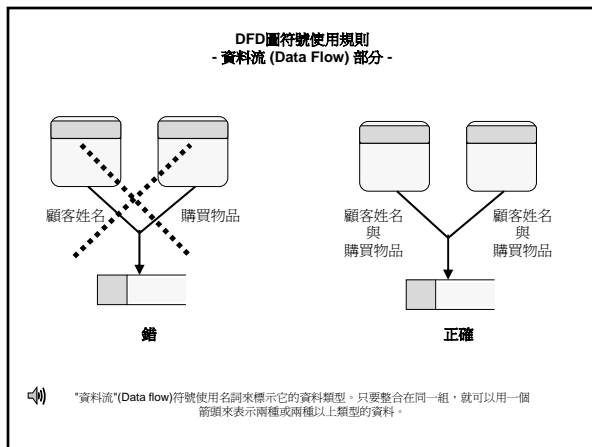
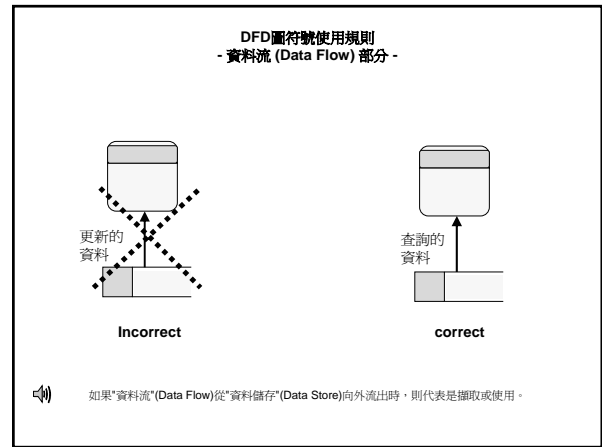
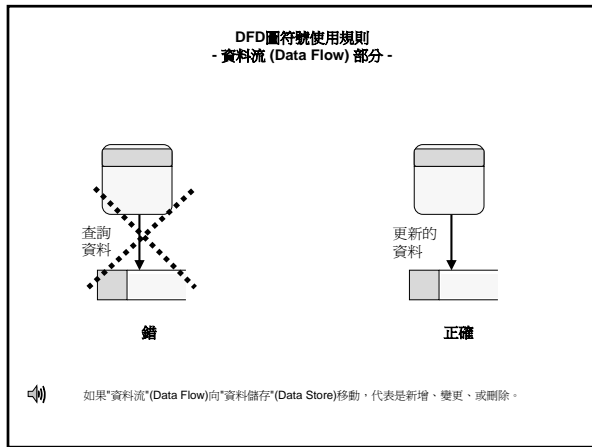
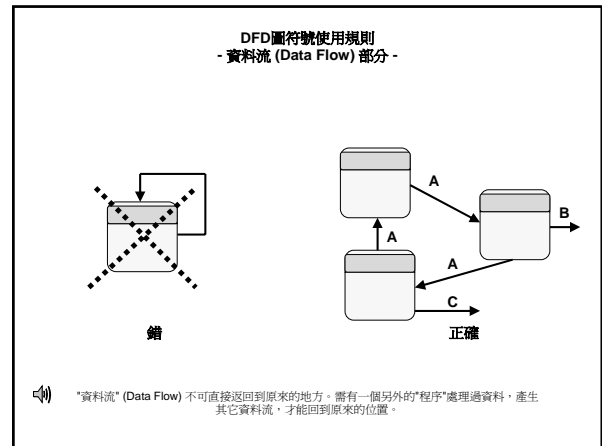
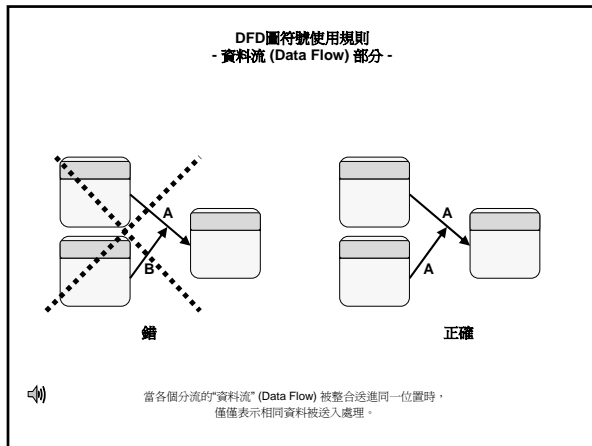
錯 **正確**

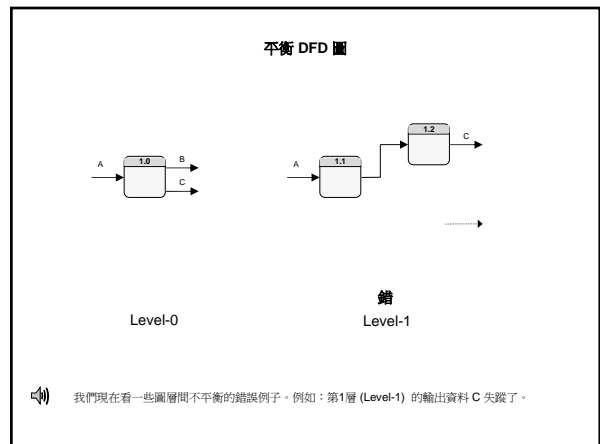
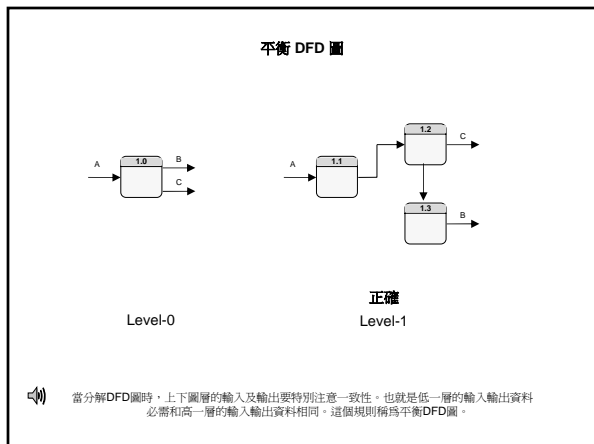
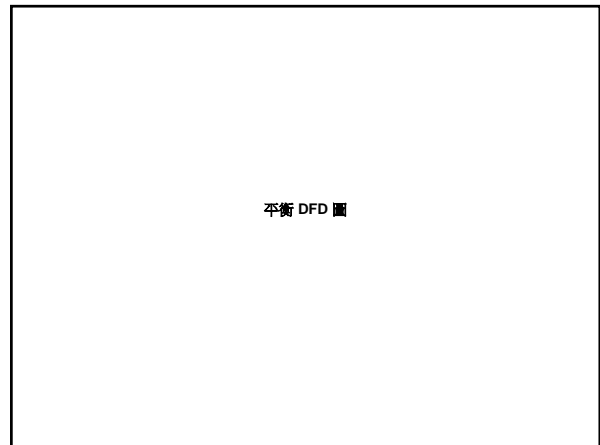
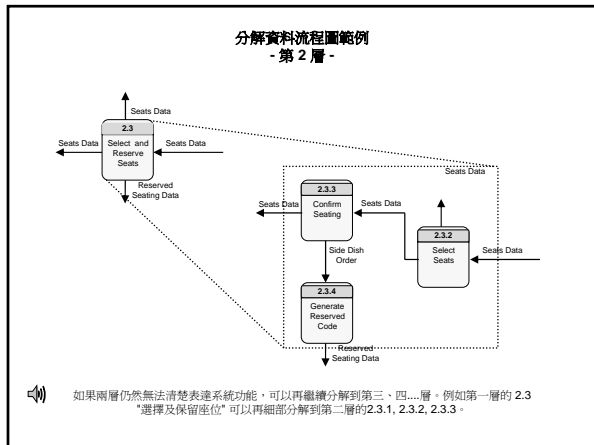
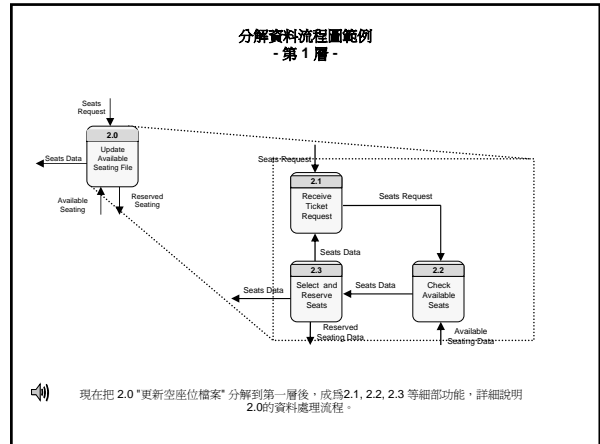
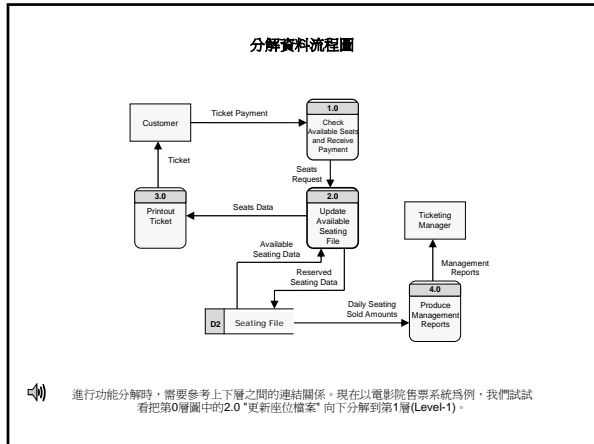
🔊 “資料流”(Data Flow)的箭頭僅可以一個方向。如果要表達資料同時被讀寫時，仍然應該用兩個“資料流”符號表示，因為發生的時間有先後順序。

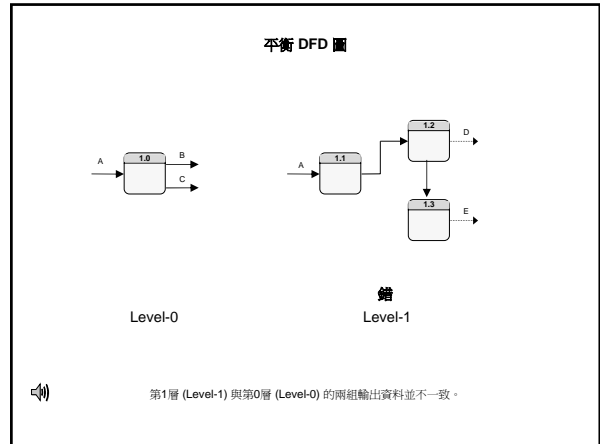
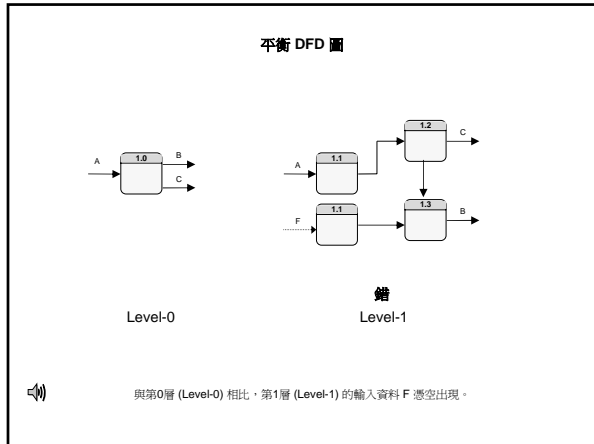
DFD圖符號使用規則
- 資料流 (Data Flow) 部分 -

錯 **正確**

🔊 當“資料流”(Data Flow)從同一點被送出，而中間出現分流時，僅僅表示相同資料被送到各個位置。







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