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Self-management of cognitive load when evidence of split-attention is present

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Self-management of cognitive load when evidence of split-attention is present

A thesis submitted in fulfillment of the requirements for the award of the degree

Doctor of Philosophy

from

UNIVERSITY OF WOLLONGONG

by

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B.A. (Psych), M. Science (Psych)
M. Psychology (Forensic)

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Declaration

I, Kylie Roodenrys, declare that this thesis, submitted in fulfillment of the requirements for the award of Doctor of Philosophy, in the Faculty of Education, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other institution.

Kylie Roodenrys

9 May, 2012
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Abstract

Students are constantly exposed to inefficient learning environments where materials are designed with a lack of consideration about the architecture of human memory. Split attention learning environments are a common cause of cognitive overload for students and the focus for this thesis was to investigate the effect on learning if students were instructed to manage split attention.

Three experiments investigated how students could manage their own cognitive load when there was evidence of split attention in learning materials. In all three experiments, participants were randomly assigned to one of three conditions:

1. Conventional split attention formatted instructional materials (Group 1: split-attention)
2. Conventional format and given guidance on how to manage split-attention (Group 2: self-managed cognitive load)
3. Integrated instructional materials (Group 3 – instructor-managed cognitive load).

Experiment 1 indicated the guidance provided to Group 2 was not utilised by the students. This was best informed through use of the think aloud protocols. Group 3 outperformed Group 1 in the post-test performances for recall, near and far transfer items - indicating the split attention effect was present for the instructional materials.
Experiment 2 included a revision of the guidance provided to Group 2. Students allocated to Group 2 were asked to manage split-attention before attempting to learn the material. This yielded more promising results for self-management of cognitive load. Group 2 outperformed Group 1 on both near and far transfer items. Group 3 outperformed Group 1 on all post-test performance items, again indicating the split-attention effect.

Experiment 3 replicated the findings of Experiment 2 with almost identical findings. The second part of the experiment extended the research to include a transfer task that sought to measure the ability of students allocated to Group 2 to apply their knowledge of self-management to a new set of instructional materials. The results indicated the students were able to transfer the self-management of cognitive load skills.

The series of experiments show definite potential for students to manage their load, if given the correct guidance that aligns with the rules governed by cognitive load theory in relation to the constraints of human memory.
Introduction

Cognitive load theory (CLT) is an instructional theory, underpinned by knowledge of human cognitive architecture, that informs the design of effective instructional materials. When instructional materials are aligned with CLT, the limitations imposed on working memory are lessened. CLT has become important in the curriculum of educational psychology programs and the teaching profession is embracing the findings of empirical research that has emerged over the last thirty years (Plass, Moreno & Brünken, 2010).

The thesis seeks to investigate a different, and thus novel, direction for the use of CLT in education. Predominantly, the research conducted about CLT has focussed on how instructional designers or educators can optimally design learning materials for their students based on CLT principles. In particular, the research has focussed on instructors manipulating cognitive load to enhance learning. This thesis, however, reports a series of experiments that examine the effects on student performance when the students themselves are provided with guidance on how to manage their own cognitive load when exposed to non-CLT compliant instructional materials. Thus, the focus of this research is whether students can utilise self-managed cognitive load strategies to facilitate learning.

University and school environments present a variety of educative experiences, some of which may not necessarily be optimal in terms of cognitive load. For example, it is unlikely that all instructional materials students are exposed to have been constructed with cognitive load considerations. One only needs to open a textbook, web page or
examine a PowerPoint lecture presentation to witness cognitively demanding methods of presentation formats. Thus, there could be potential benefits if students are equipped with strategies that can assist them in managing cognitive load in their everyday learning environments.

This research study focuses on investigating strategies that assist in managing split-attention. Split-attention is one of many effects within the CLT framework and was selected because it is one of the most common effects students encounter.

The structure of this thesis is as follows:

- Chapter 1 introduces the crucial element to any research involving use of CLT – human cognitive architecture. This includes a review of human memory and the information processing systems. It is followed by a review of knowledge structures and processes, metacognition and transfer. Discussion of CLT and its alignment with recent work on the evolutionary cognitive processes is examined.
- Chapter 2 explains the rationale for this current research by presenting a synthesis of the CLT ‘effects’ generated by empirical research and discussing criticisms of and challenges for, CLT research.
- Chapter 3 discusses the research design.
- Chapters 4, 5 and 6 report the findings of the three studies that comprise this thesis.
- The final chapter, Chapter 7, summarises the key findings and limitations of this research, discusses the implications for CLT and suggests a future research
pathway to seek further understanding about the *self-management of cognitive load* effect.
Chapter 1
Cognitive processes that underlie learning

1.1 Introduction
This chapter focuses on the cognitive structures and processes that underlie learning. These processes and structures form the basis of cognitive load theory (CLT), which provides the theoretical framework for this thesis. Information-processing frameworks as first proposed by Atkinson and Shiffrin (1968), and memory models, as proposed by Baddeley (1986) and Moreno (2010a) are a major focus of this chapter. Recent research on the role of metacognition and self-regulatory processes within the information-processing framework is examined. The chapter concludes by discussing recent developments in the relationship between human cognitive architecture and other natural processing systems (Sweller, 2008: Sweller & Sweller, 2006).

1.2 Advancements in Cognitive Psychology
Since the late 1960s there have been significant advancements in cognitive psychology that have become a strong focus for educators. The emphasis of the learner actively constructing meaning and knowledge has led to more sophisticated understandings about the role of perception, thought and memory processes. The emergence of powerful concepts such as schemas, levels of processing and constructive memory from this ‘cognitive revolution’ have made important inroads in educational psychology (Bruning, Schraw, Norby & Ronning, 2004). For example key advances within cognitive psychology that have influenced educational psychology include:
• learning is a constructive (not receptive) process and extended practice is a necessary component for the development of cognitive skills (Prawat, 1996);

• mental frameworks (schemata) organise memory (Schneider & Shiffrin, 1977);

and

• the development of self-awareness and self-regulation is critical to cognitive growth (Zimmerman, 1990).

This thesis focuses on educational psychology by examining issues related to the information-processing model. The model presented by Moreno (2010a) comprehensively explains the relevance of information-processing models in relation to CLT and thus serves as a focal point in this chapter.

1.3 Human Cognitive Architecture

Research about human memory has generated a number of models that illustrate the way in which information is processed, with consensus being that the human cognitive system comprises a combination of a limited working memory and a ‘powerful’ long-term memory, which is facilitated by learning mechanisms such as schema development and automation (Sweller, 2008). The main features of this human cognitive architecture are illustrated in Figure 1.1 (Moreno 2010a) and discussed below.
Figure 1.1: Cognitive Processes and Memory Systems from an information-processing framework (Moreno, 2010a, p. 213)

Use of the term ‘human cognitive architecture’ assumes that most cognitive activity is guided by the large and potentially unlimited store of information held in long-term memory, but it is in working memory (a limited capacity memory store) where crucial cognitive processes occur, that is, “working memory is where thinking occurs” (Moreno, 2010a, p. 202).

Information-processing models that incorporate discrete memory systems date back to the 1960’s (Atkinson & Shiffrin, 1968). The modal model of the information-processing system consists of a sensory memory, short-term (working) memory and long-term...
memory (Atkinson & Shiffrin, 1968). This model has been likened to a computer, where working memory is analogous to a computer’s RAM (random access memory), that is temporary and limited in capacity. Thus, the processing system of a computer, where data is input, then processed and an output is provided (such as storing of information), is similar to the processing system of a human’s internal memory. The modal model information-processing system assumes learners are active processors of information, not simply passive receivers of knowledge.

Research work by George Miller (1956) was fundamental to the development and understanding of the information-processing framework and our understanding of memory. His seminal paper ‘The magical number seven plus or minus two’ (Miller, 1956) was pivotal to the development of understanding the limited capacity of short-term memory (later termed working memory). Miller’s research focussed on short-term memory and the relatively poor ability of humans to recall large amounts of new information unless transfer into a more permanent form occurs.

The central feature of the modal model is the number of discrete systems (with specific functions) that interact to allow incoming information to be processed. As illustrated in Figure 1.1, information is processed via sensory memory, temporarily stored in working memory and if rehearsal strategies are employed, the information is likely to be transferred to long-term memory. The information stored in long-term memory influences processing of new information, as previously acquired knowledge impacts on the processing capacity of working memory. The three separate memory structures of the modal model are discussed in detail below.
1.4 Sensory Memory
Sensory memory comprises a set of registers relating to the human senses: visual (see), auditory (hear), tactile (touch), olfactory (smell) and gustatory (taste) (see Figure 1.1). This is the first memory structure that temporarily holds stimuli from the environment until it can be either further processed or is lost. For example, an artist looks at a scene and then moves their eyes to a blank canvas. The artist tries to recreate the image on the canvas by using the information that is in their visual working memory.

Prior knowledge greatly influences perception, recognition and the processing of meaning. One’s own knowledge base influences what one sees, hears, touches, smells and how one uses their senses (context and perception) (Bruning et al., 2004). For example, being taught how to read enhances one’s ability to follow the text presented. An interest or understanding of memory research would also influence one’s likelihood to read this thesis. Those unfamiliar with memory research would find it difficult to recognise specific terms referred to in this thesis and, thus, would take longer to process the information contained in this thesis than someone who is familiar with the content. Therefore, sensory memory is a very important facet for working memory, as it is the filter that allows stimuli to activate working memory resources.

1.5 Working Memory
Working memory is used to transfer information into long-term memory but also to retrieve information from long-term memory. As Figure 1.1 shows, information enters working memory through sensory memory or is retrieved into working memory from long-term memory. Like sensory memory, working memory is limited in both capacity
and duration for new information. The work by Baddeley and Hitch (1974) was fundamental to changing the term ‘short-term memory’ to ‘working memory’ to emphasise the active role played by humans in the construction of knowledge. They expanded the research of George Miller, which emphasised the limited capacity of short-term memory, by adding components that make important distinctions to the kinds of cognitive processes used in working memory (this is explained below and illustrated in Figure 1.2). The contents of working memory are what a person’s current focus of attention is (Cowan, 2005) and some theorists have likened working memory to consciousness (Sweller, 1999), for example: “we are conscious of what is in working memory and not conscious of anything else” (Sweller, 1999, p. 4).

There are a number of models that explain the complexities of working memory, for example: Atkinson and Shiffrin (1968) and their view that information processing is activated via the senses then moves into short-term memory and long-term memory; the three-component working memory model by Baddeley (1986, 2000); Cowan (2005) and his view that working memory is not a separate system but a part of long-term memory; and Miyake and Shah (1999). Despite their variances, each of these models emphasise the importance of the two key features of working memory:

1. Capacity is limited, thus constraining cognitive performance (Miller, 1956; Simon, 1974).
2. There are limits in duration (Peterson & Peterson, 1959). Information can only be held in working memory for 15 to 30 seconds (Moreno, 2010a).
Because of the limits in capacity and duration, if the information in working memory is not encoded into a more permanent form it will decay from working memory and be forgotten (Sweller, 1999), or it might be replaced by incoming information that is competing for the limited working memory capacity. Revision and rehearsal strategies are essential if the ‘to be learned information’ is to be transferred to long-term memory. For example, when attempting to remember a telephone number, this information will only be held in working memory for a short period of time. A rehearsal strategy must be utilised to increase the likelihood that the telephone number will be remembered, otherwise it is likely to be forgotten.

As mentioned previously, Baddeley and Hitch (1974) were influential in renaming short-term memory to working memory. Baddeley’s model of working memory (Baddeley 1986) illustrated in Figure 1.2 has been a highly influential theory of working memory. This model suggests there are three structural components within working memory. These include a central executive (also known as the executive control system) and two slave systems: the phonological loop and the visuo-spatial sketch-pad (Baddeley, 2012).

Figure 1.2: Baddeley’s model of working memory in 1996 (Baddeley, 2012, p. 11)
As Figure 1.2 illustrates, the two slave systems specialise in processing temporary information from auditory and verbal domains. The phonological loop processes verbal information. The visuo-spatial sketchpad controls incoming visual or spatial information. The central executive oversees both of these processes and governs, co-ordinates and controls the activities within working memory. The central executive allocates incoming information to either of the two slave systems as well as retrieving the relevant information stored within long-term memory that assists with assimilation of the incoming data (Conway, Jarrold, Kane, Miyake & Towse, 2007). The visuo-spatial sketchpad, phonological loop and central executive are all considered the working memory component of the diagram, a series of fluid systems that only require temporary activation. Whereas the bottom part of the diagram (Figure 1.2) represents long term memory with permanent or ‘crystallised’ skills. The 1986 model is considered a modification of the original Baddeley and Hitch (1974) model that acknowledges the links between working memory and long-term memory.

Baddeley revised his model in 2000 to include a fourth component, called the episodic buffer. This addition to the model provides a better explanation for more complicated aspects of executive function within working memory. There is greater attention on the process of integrating information rather than the “isolation of the subsystems” (Baddeley, 2000, p. 417). The phonological loop plays an important role in long-term phonological learning (not just short-term storage). The episodic buffer assists by storing information in a multi-dimensional code and provides a ‘buffer’ for the slave systems (phonological loop and visuo-spatial sketchpad). The introduction of the buffer is demonstrated in Figure 1.3 below.
The episodic buffer is controlled by the central executive and holds episodes or ‘chunks’ in a multidimensional code. It emphasises the importance of co-ordinating working memory and long-term memory systems.

The majority of current working memory theories all agree that long-term memory has an integral role in working memory. They also agree that working memory has constraints in relation to capacity and duration. Baddeley (2012) claims “There are a number of ambitious models of working memory that I regard as broadly consistent with the multicomponent framework, although each has a different emphasis and terminology” (p. 19). This neatly summarises the view that many of the theories have commonalities for the basics of working memory components, but vary in their use of terminology.

**1.6 Long-Term Memory**

Long-term memory (LTM) refers to our limitless knowledge storage system. LTM allows one to recognise familiar faces, recall a birth date, drive a car, play tennis and write an email (Baddeley, 2012; Moreno, 2010a). One is unaware of the contents of LTM until it
is brought into working memory. The information stored in LTM is largely permanent and thought to be highly structured (Sweller, 2008).

Unlike working memory, rehearsal is not crucial to the maintenance of items stored within LTM. The recall of items stored in LTM depends on the understanding of what is being asked and how to access it. LTM contains a complex set of skills and knowledge base that allows problem solving, thinking and perceiving. The knowledge structures held in LTM are referred to as schemas or schemata (Kalyuga, 2006).

Schemas are constructs that allow multiple sources of information to be grouped and categorised for future reference. Schemas develop from our stored body of knowledge in LTM about a topic or area. When new material is encountered, we relate the material to existing schemata and modify accordingly (Ashcraft, 2005). For example, a child learning about birds will construct a schema that includes information that relates to general features of a bird, types of birds associated with different shapes, sizes, colours, place of origin, and soon the schema allows the child to assess whether the object they encounter can be identified as a bird or not.

Schemas are essential to learning. They are also very useful in problem solving due to the ability to access relevant information required to solve problems. Schemas are constructs that exist in a hierarchical manner. For example, lower-order schemas (such as letters of the alphabet) are subsumed into middle-order schemas (such as words) that are integrated into higher-order schemas (such as phrases/sentences).
Schemas will vary dramatically between novices and experts and, as a result, affect one’s ability to solve problems. An expert has access to higher order schemas that can be utilised to solve complex problems. A novice does not have access to such higher order schemas and thus needs to process and develop ideas that might fit within their established schemas (Sweller, 1999).

A key study, conducted by de Groot (1965), illustrated the critical function that schemas serve for learning. De Groot conducted a number of experiments to examine chess players ranging from amateur/novice to expert/chess ‘masters’. His influential research altered the way human cognitive architecture was viewed at the time because it highlighted the important role memory played in distinguishing an ‘expert’ from a ‘novice’. De Groot’s (1965) study illustrated the importance of schemas in LTM by showing that chess masters defeated less able chess players due to the ability to recognise the chessboard configurations they have encountered in the past. The chess masters had accumulated and assimilated more chessboard configurations (patterns) into their LTM than the less-able players and were able to draw on this schema, which resulted in a superior performance. The chess masters did not have to work out the ‘best’ move because they knew the best move based on their prior knowledge gained through thousands of board configurations played from real games throughout their experience.

Subsequent research by Chase and Simon (1973) replicated the de Groot study, but also tested memory using random chess configurations that were not taken from real chess games. The random configuration was used to test if there was still a difference between expert and novice players. Expert players did show a superior memory for the
configurations taken from real chess games but there was no significant difference between the two categories of players when the board configurations were random. Therefore, it was suggested that expert players used their large store of domain specific knowledge (schemas in LTM) to make a chess move. The novice chess player had not acquired such knowledge and experience, thus had limited schema and could only rely on working memory to assist in the decision of what might be ‘a good chess move’.

Schema automation occurs when information can be processed with minimal cognitive effort. Sweller (1999) claimed that an “automated process is one that can be carried out with minimal conscious thought” (p. 14). Schema automation reduces the need for working memory resources and enables problem solving to occur without conscious effort. Examples of automation include activities such as adults driving a car or reading a newspaper. Automation is the result of direct instruction, repetition and deliberate practice (Kalyuga, Ayres, Chandler & Sweller, 2003). It requires a great deal of practice, therefore, automated schemas only develop for “aspects of performance that are consistent across problem situations, such as routines for dealing with standard game positions in chess, for operating machines and for using software applications” (van Merriënboer & Sweller, 2005, p. 149).

Novices tend to have superficial ill-defined schemas in an area. As a result, the novice needs to chunk the incoming information in working memory so that it increases the likelihood that information is transferred into LTM. This is the process of schema construction. Whilst schema construction is critical for solving similar problems, schema automation is crucial for problem transfer (Cooper & Sweller, 1987; Kotovsky, Hayes &
Simon, 1985). Deliberate practice further reinforces the schemas and enables one to solve more difficult or complex problems. Chess masters have developed automated schemas through years of deliberate practice with a comprehensive store of multiple board configurations.

Schema construction and automation are essential to learning and instruction (Kalyuga et al., 2003). If learners are not directed toward activities that enhance the construction and automation of schemas in long-term memory, then learning may be inhibited. Cognitive load theory, which is the framework for this thesis, is particularly concerned with developing instructional techniques that lessen the load on working memory and facilitate the construction and automation of schemas.

In sum, LTM is considered an important aspect for all cognitive activity. The once-assumed unitary components of working memory and LTM are now considered more complex with the need for a central executive that co-ordinates the systems and a buffer that can integrate information from a variety of sources (Baddeley, 2000). The development of schemas is crucial to the subsequent learning of new material that enables transfer to LTM.

This section has outlined the three memory structures inherent within the information processing approach: sensory memory, working memory and long-term memory. The next section discusses the role that metacognition plays in the learning process.
1.7 Metacognition
Information-processing models of memory assist in understanding how we deal with information as it is accessed, stored and retrieved. How one manages or thinks about this cognitive process involved in learning is referred to as metacognition. Metacognition is the knowledge about one’s own thinking processes. Figure 1.4 suggests there is considerable overlap in the way memory and metacognition function. As is evident in the modal model, metacognition is a broad concept that can assist encoding, storage and retrieval of information presented to memory structures. For example, a teacher who asks students to wear name tags for several days, because she is aware of her problem remembering names, is displaying metacognitive awareness of her memory limitations. Another example includes the student who takes notes in class. These two examples highlight how learners can implement a particular strategy to assist their learning, based on their awareness of their cognitive abilities.
‘Metacognition’ was coined by John Flavell, who was a founding researcher in the area. His highly cited paper: ‘Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry’ (Flavell, 1979), attracted attention from cognitive and educational psychologists due to its unique use of the learner’s beliefs regarding knowledge. Flavell defined metacognition as “one’s knowledge or beliefs about what factors or variables act and interact in what ways to affect the course and outcome of cognitive enterprises” (1979, p. 907). He also alluded to the active monitoring of these processes in relation to the goal in mind.

Although knowledge about cognition (how we learn) is important for learning to occur, this knowledge cannot be extended unless the student is able to control it (Moreno, 2010a). Thus three essential skills are required for metacognitive development (Moreno, 2010a, Bruning et al, 2004):

1. Planning: deciding on how much time to invest in the task, what strategies should be employed, and so on

2. Regulation: monitoring progress toward a learning goal and revising strategies if the goals are not being met (e.g. pacing, reviewing); and
3. Evaluation: making a judgement of the learning outcomes. This involves asking questions such as ‘Did I achieve what I intended to?’, ‘Was that the best strategy to use?’ or ‘What have I learned?’

Metacognitive knowledge enables more accurate comprehension, monitoring and development of conceptual and procedural knowledge related to a domain (Panaoura & Phillippou, 2007). For example, a maths student may be aware of the concepts they learned in an algebra class. They may have learned some strategies that assist in solving algebraic equations, which is part of procedural knowledge. How and when to apply the algebraic strategies to solve varied problems is conditional knowledge. Although knowledge about our knowledge of learning is important for learning, this knowledge cannot extend a student’s growth of understanding unless the student engages in the second part of metacognition, which is control (Moreno, 2010a).

A student’s control of cognition can dramatically improve their cognitive processing and learning. For example, the student who turns off the television whilst completing their homework demonstrates an awareness that the distracting device is impeding her efforts to concentrate on the task being completed (Moreno, 2010a).

Metacognition appears to be more beneficial when instructional goals are complex. Simply learning a set of facts or the steps required in a skill can be assisted via a range of strategies including mnemonics, rehearsal or methods designed to assist placing facts into memory structures. When the information to be learned is more complex in nature, such as learning the application of a theory, instructional goals need to be broader in scope to
assist transfer. Activities that assist in schema activation, that is, the retrieval of schemas into working memory, are more likely to yield improved results. Metacognition assists with schema activation as it helps learners to manage their own encoding, storage and retrieval. Importantly, metacognitive strategies are transferable across learning domains (Bruning et al. 2004).

Research indicates that metacognitive skills tend to improve with age up to a point. Research concerning metacognition has found that as children get older, they are more aware of their cognitive skills and better able to employ strategies that will assist the assimilation of new information (Desoete, Roeyers & Buysse, 2001; Joseph, 2006; Veenman, Wilhelm & Beishuizen, 2004). However, it is argued that learners have difficulty developing self-reflective abilities on their own and require specific guidance for the acquisition of metacognitive skills, thus, explicit teaching of metacognitive skills, particularly during primary school years is important (Joseph, 2006; Moreno, 2010a). Metacognitive strategies should be modelled by teachers to help students acquire these skills and become more self-regulated learners (Moreno, 2010a).

In sum, metacognition research suggests it is useful to assist students with skills to be aware of their thinking strategies in an effort to become self-directed learners. This, in turn, heightens their ability to transfer learning to new situations – the focus of the next section.

1.8 Transfer
The optimum conditions required for students to transfer knowledge learned during problem-solving exercises has been extensively researched (see Bassok & Holyoak,
1989; Catrambone & Holyoak, 1989; Chi, Bassok, Lewis, Reimann & Glasser, 1989; Cooper & Sweller, 1987; Holyoak & Koh, 1987). As previously mentioned, schema automation is crucial for problem transfer. The term ‘transfer’ refers to: “a phenomenon involving change in the performance of a different task…transfer may be ‘near’ (e.g. within the same type of problem in the same subject domain), or ‘far’ (e.g. between domains)” (Billing, 2007, p. 486). A review of the literature about the transfer of cognitive skills across learning domains conducted by Billing (2007) found that transfer is more likely to occur when general principles of reasoning are combined with self-monitoring practices for a variety of contexts. This is where the importance of metacognition is emphasised, as the use of metacognitive strategies is especially important for transfer of knowledge. Also, it is asserted that teaching critical thinking skills is only effective for transfer when the ‘to be learned’ principles are linked with practical examples (Billing, 2007).

This thesis is specifically concerned with whether the skills to self-manage cognitive load can be learned and transferred within the same learning domain (near transfer) and to other learning domains (far transfer). This can be considered a metacognitive strategy to make optimum use of limited working memory.

1.9 Extending Understanding about Human Cognitive Architecture

As explained in this chapter, cognitive psychologists have used the information-processing model as a framework to explain how memory influences learning. However, developments over the past decade are extending our understanding of human cognitive architecture by linking the information-processing model with modern
evolutionary theory (Sweller, 2006, 2010b): “By considering human cognition within an evolutionary framework, our understanding of the structures and functions of our cognitive architecture are being transformed” (Sweller, 2010b, p. 29).

The premise of this recent work is that through evolution by natural selection, humans have evolved to perform a range of cognitive activities that vary in complexity and, thus, have differing levels of cognitive consequences (Sweller, 2004, 2006, 2010a: Sweller & Sweller, 2006; Sweller, Ayres, & Kalyuga, 2011). The theoretical framework of evolutionary educational psychology distinguishes between biologically primary and secondary knowledge (Geary, 2008). Biologically primary knowledge relates to knowledge that is readily learned, often without conscious thought and being explicitly taught. This capacity has been acquired through our evolution over many generations. Examples include listening and speaking, recognising faces, and a baby learning to walk. Biologically secondary knowledge refers to the knowledge one acquires that requires cognitive effort. Biologically secondary information essentially encompasses everything that is taught in educational institutions from early childhood to university studies. If one were to read and write simply by exposure (as appears the case with speaking and listening or ‘primary knowledge’) schools would not be needed. Humans have not evolved to read and write, thus, the last couple of hundred of years has seen the development of the science of reading and a gradual improvement in the skills we have acquired to assist in instruction (Sweller, 2007). The focus of the current thesis is investigating strategies that will improve the learning of biologically secondary material.
Human cognition can be characterised by five principles that explain the functions and processes a learner engages in to acquire biologically secondary knowledge (Sweller, 2010b, Sweller et al. 2011):

1. **Information store principle**: Relates to the requirement of a large storage system that governs activity. This relates to LTM and its unlimited capacity.

2. **Borrowing and reorganising principle**: Refers to the accumulation of information by borrowing and reorganising information from other sources. For humans, information stored in LTM is organised as schema but this information has been ‘borrowed’ by the sharing of schemas from the LTM stores of others (e.g., listening to what people say, imitating what people do or reading what people have written).

3. **Randomness as genesis principle**: Refers to the creation of knowledge. This allows one to acquire knowledge after random generation and test procedures occur. An example is problem solving and when one comes to a ‘dead end’. The learner needs to revise their steps using knowledge stored in LTM and continue the process of random generate and test until the solution is devised. In evolution, all biological variation comes from random mutation, a form of random generation and test.

4. **Narrow limits of change principle**: Emphasises that the human cognitive architecture is only able to deal with small amounts of novel information (in working memory) and changes to LTM occur incrementally and over a long period of time, that is, over a lifetime. Working memory allows humans to narrow down the amount of information one needs to deal with at any one time. This ensures we are not overwhelmed by our environment and can operate effectively, making more use of our powerful long-term memory stores.
5. *Environmental organising and linking principle:* This principle relates to retrieving information stored from LTM into working memory to function and respond in a given environment (Sweller et al., 2011). Stored information held in LTM is structured in an organised manner and, thus, is different to information received from the environment; the process of retrieving information held in LTM into working memory is different to processing novel information entered into working memory from sensory memory (Sweller et al., 2011). Furthermore, “there are no known limits to the duration that information from long-term memory can be held in working memory” (Sweller et al., 2011, p. 48).

The analogy between the human cognitive architecture and other natural process systems helps to further understanding of how information is processed using our memory systems and how learning occurs in an incremental manner. It also explains the pivotal link between working memory and LTM.

The work of Sweller and Sweller (2006), and Sweller (2008, 2010a) emphasises the critical importance of understanding human cognitive architecture when designing learning material. CLT asserts that attempts to introduce instructional procedures that ignore human cognitive architecture are likely to be ineffective (Sweller et al., 2011). Given that most of what is learned in schools and universities is biologically secondary information, it is subject to the limits of and constraints of human memory structures and processes. This thesis deals with biologically secondary knowledge for which cognitive architecture plays a pivotal role in learning.
1.10 Summary
This chapter has examined the cognitive architecture involved in human cognition and has explained the guiding framework for cognitive load theory, which is the focus of the current thesis. The three main components of the human cognitive system: sensory memory, working memory and long-term memory, were discussed. The limits of working memory were emphasised in relation to the endless store of LTM. The process of schema construction and automation explained in detail the overarching role of metacognition on the memory process. The chapter concluded by discussing the latest developments that are extending understanding of human cognitive architecture by considering modern evolutionary theory. Overall, this chapter has provided an outline of the underlying cognitive systems that are central to the work of the current thesis.

The next chapter provides a detailed examination of CLT and the multiple effects that have emerged from the research. It also examines how cognitive load theory relates to the focus of this thesis, which is self-management of cognitive load.
Chapter 2

Synthesis of Cognitive Load Theory research

2.1 Introduction
Cognitive load theory is a psychological theory that attempts to explain what effect instructional design has on an individual’s learning (Moreno & Park, 2010). Professor John Sweller pioneered cognitive load theory in the late 1980’s and it has been developed based on established principles of human cognitive architecture (Sweller, 2010b).

Over the last three decades, Cognitive load theory (CLT) has generated a set of instructional principles that facilitate learning by taking into account the limitations of human cognition (Plass, Moreno & Brünken, 2010). This chapter examines CLT in detail and provides a rationale for the research reported in this thesis. The chapter begins by explaining CLT, followed by a synthesis of the research conducted on the different cognitive load effects. Particular emphasis is given to the split-attention effect, as it is the cognitive load effect examined in this thesis. The current debate about CLT is presented and recent conceptualisations of the theory are discussed. The chapter concludes by explaining why the concept of self-managed cognitive load is a research gap in CLT research.

2.2 An Overview of Cognitive Load Theory
CLT is based on 30 years of experimental research (examples of seminal empirical work include: Chandler & Sweller, 1991; Cooper & Sweller, 1987; Cooper, Tindall-Ford, Chandler & Sweller, 2001; Kalyuga, Chandler & Sweller, 2000; Mayer & Moreno, 1998; Moreno, 2006; Paas, 1992; Sweller & Chandler, 1994; Tindall-Ford, Chandler & Sweller,
This has resulted in the development of a set of universal principles aimed to optimise learning through knowledge of the cognitive effects responsible for efficiency (many of the effects are discussed in Section 2.4). Cognitive load is not a new concept in psychology as its roots in human factors and psychology date back to Moray (1979), where a synthesis of the research about mental workload and its measurement is presented.

Cognitive load refers to the demands on working memory at any moment in time for a learner (Kalyuga, 2010). The amount of units of information, referred to as elements (Sweller, 2010b), relate to the load on working memory. The more elements that need to be processed in working memory at any one time, the higher the cognitive load. For example, the number sequence 94571945 has eight elements if processed separately in working memory. They may be difficult to recall due to the high number of elements that are required for processing within our limited working memory. Too many elements may burden working memory and this impedes the ability to process the incoming information. If the elements relate to schemas held within long-term memory (i.e., if the number above was your home telephone number), the information is more likely to be recalled. Alternatively, a learner can utilise strategies to make more efficient use of working memory. One strategy is ‘chunking’ (Moreno, 2010a) which combines the elements. For example, 89421945 is more difficult to recall than 8942 and 1945, where elements are combined like that of a telephone number. By adding meaning to the ‘chunk’ 1945, such as highlighting that this date marked the end of World War II, the number is more likely to be recalled.
CLT states there are three types of cognitive load that have an effect on working memory. These are intrinsic, extraneous and germane load. Intrinsic and germane load are considered productive forms of cognitive load as they may assist learning while extraneous load is considered unproductive and not directly related to learning (Kalyuga Renkl & Paas, 2010). Each of these three types of cognitive load is discussed below.

2.2.1 Intrinsic load
Intrinsic load refers to the intrinsic nature or complexity of learning material. Intrinsic load cannot be directly altered, but it can be lessened by splitting tasks into manageable parts. It can “only be altered by changing the nature of what is learned or by the act of learning itself” (Sweller, 2010a, p. 124). Intrinsic load depends on the number of related elements that need to be processed in working memory and the extent to which these elements relate to each other (element interactivity). An example of low element interactivity is learning isolated words of a foreign language, such as the Spanish term for ‘black’. Only one word needs to be learned so the task is considered low in element interactivity. Interactivity means that elements must be coordinated in memory to learn a task. Many elements can be learned in isolation without reference to other elements. For example, a person learning Spanish as a foreign language might learn a few phrases (such as greetings) to use on a vacation to a Spanish speaking country. In isolation, these words and phrases are easy to recall and remember, because the elements of the material to be learned do not interact with each other. However, if content is complex, learners are required to utilise working memory resources to coordinate multiple elements. Complex content would be coordinating the learned words of the foreign language into a sentence or having a fluent Spanish speaker use the words in a sentence. Understanding of the
information requires the coordination of many elements, including an understanding of grammar, syntax and meaning and when spoken to in Spanish, the complexity is increased due to high levels of element interactivity. This increases the intrinsic load of the task as it involves more interacting elements that require simultaneous processing (Clark, Nguyen & Sweller, 2006).

Material with high element interactivity is difficult but made easier once schemas are developed by a learner to assist the processing of interacting elements. Prior knowledge influences intrinsic load “in that a large number of interacting elements for a novice may be a single element for an expert who has integrated the interacting elements in one schema” (Moreno & Park, 2010, p. 1). For example, those for which Spanish is a foreign language and who have practised speaking in Spanish for many years have gradually developed a schema for the language that enables them to efficiently process the interacting elements required to speak fluently. Their prior knowledge of Spanish words and phrases makes sentence construction an efficient process compared to a novice who is attempting to learn the language. For the expert, construction of a sentence is considered a single element, yet for the novice there are many interacting elements that are yet to be mastered to be able to construct a sentence. Thus, the complexity of the learning content has a direct effect on cognitive load.

2.2.2 Extraneous load
In contrast to intrinsic load, extraneous load is related to the processes unrelated to learning, that is, the way in which instructional materials are designed and presented to a learner. This load can be modified and manipulated by the instructional designer by
changing the instructions and activities provided to the learner. Extraneous load may be high due to the format or layout of instruction. An example of high extraneous load is when the learner is required to integrate text and diagram from two separate sources of information. This is known as the split-attention effect (explained in more detail below).

Seminal research that examined this phenomenon was conducted by Chandler and Sweller (1991). Figure 2.1 represents the split-attention effect because, in order to understand the information presented in Figure 2.1, segments of text need to relate to the matching entities in the diagram. To understand the text “make sure main switch is ‘on’ and all fuses are ‘in’” requires the learner to hold the text in working memory while searching the diagram for the main switch representation (Chandler & Sweller, 1991). If the learner has to integrate both sources of information to extract meaning, working memory can become overloaded. This is because the search and match process, which is required to integrate both sources of information, needs to be completed before learning of the actual content can proceed. If these instructional materials are redesigned to integrate the text with the diagram, that is, place appropriate text next to the appropriate parts of the diagram, then learning could be enhanced because less working memory resources are required to process the information (van Merriënboer & Ayres, 2005). As seen in Figure 2.1, an electrical diagram and text were presented to electrical apprentices in an industrial setting. In order to make sense of the information, the diagram and text needed to be integrated. The physical integration of both text and diagram is important as each source of information is unintelligible in isolation. Thus the participants in the study needed to mentally integrate the two sources to make sense of the information, in turn putting extra load on working memory resources. In contrast, Figure 2.2 illustrates an
integrated format where extraneous load has been reduced by lessening the need to search and match the separate sources of information.

Figure 2.1: Split-attention instructions on a test of electrical resistance for installation testing (Chandler & Sweller, 1991, p. 299)
2.2.3 Germane load

Germane load refers to the resources imposed on working memory that are directly relevant to learning, that is, the cognitive effort that is directed toward schema construction and automation (Moreno, 2010a). The primary goal of instruction is to reduce extraneous load to maximise the resources of working memory that are free to focus on activities that allow schemas to be stored in long-term memory (germane activities).
In its early stages, CLT research primarily focussed on sources of extraneous load, schema construction and the demands sourced by problem solving (e.g. Sweller, Chandler, Tierney & Cooper, 1990). Researchers then examined intrinsic load and its relation to the need to optimally design learning materials in an effort to reduce extraneous load (e.g. Sweller & Chandler, 1994). The next stage of CLT development was the study of germane load, which was first introduced by Sweller, van Merrienboer and Paas (1998). Unlike extraneous and intrinsic load, germane load “has a positive relationship with learning because it is the result of devoting cognitive resources to schema acquisition and automation rather than to other mental activities” (Moreno & Park, 2010, p. 17).

The addition of germane load to CLT prompted a revision of the additivity hypothesis, which assumes that all sources of cognitive load (intrinsic, extraneous and germane) are additive, in that, when combined they cannot exceed the resources of working memory, if learning is to occur. Intrinsic load creates a platform for learning that can only be reduced by constructing additional schemas or automating already established schemas (Moreno & Park, 2010). Instructional materials that increase working memory resources, targeted at improving intrinsic load, have the benefit of improving germane load to extend the limits of working memory. Once maximum working memory capacity is reached though, efforts to increase germane load can be counterproductive and, thus, considered extraneous load. Therefore, the balance needs to be right to ensure working memory resources are used effectively. More research, however, is required to investigate the interactions between the various categories of cognitive load (Sweller, 2010a).
An example of germane load is illustrated in Figure 2.2. Integrating the text and diagram makes it easier to learn the information because the majority of working memory resources are germane to the learning task and thus directed toward schema development. For example, the results from the Chandler and Sweller (1991) study suggested the electrical trainees who were presented with the integrated diagram showed significantly better learning of the material presented. This was demonstrated during immediate and three-month follow-up tests focused on practical tasks and conceptual understanding. Extraneous load was reduced by lessening the need to search and match information from the diagram with its relevant text components, providing opportunity for working memory resources to be devoted to germane activities. Because the information was retained at three-month follow-up, this suggests that schema development occurred, which infers the learning activities were germane.

Other examples of germane tasks include the use of worked examples to foster transfer of learning. Instructors might increase the diversity of examples to improve learning outcomes (via rich schema development) (Paas & van Merriënboer, 1993). This assists in the development of schemas, especially for the novice who has little access to information relevant to the content of the to-be-learned material. By providing a number of diverse examples, schemas develop and working memory resources are more available. When compared with conventional problem solving, worked examples lessen the load on working memory (Kirschner, Clark & Sweller, 2006). For worked examples, cognitive resources are directed toward recognising and remembering problem structures and application of rules, as demonstrated by the examples. The worked example effect is discussed in more detail below.
In summary, germane load is an important aspect to consider when designing learning materials. It has the ability to assist the learner by devoting relevant resources toward the development of schemas.

2.3 Measuring cognitive load
There are many techniques used by CLT for measuring cognitive load. For example, Sweller (1988) was able to demonstrate through use of a computational model (number of steps to solution, time taken to answer the problem), that problem solving through a means ends strategy is very high in cognitive load compared to techniques that were lower in cognitive load (e.g., goal-free problems) that lead to superior learning. Cognitive load theorists have also employed dual-task techniques to measure cognitive load. Dual-task techniques measure load by asking participants to respond to a secondary task that is not related to the instructional material presented (e.g., recalling a letter of a computer screen) while engaging in a primary task (e.g., studying instructional material). Low performance on a secondary task suggests a primary task is high in cognitive load because there are limited working memory resources left to perform the secondary task. High performance on a secondary task suggests a low cognitive load primary task, because there are working memory resources available to perform the secondary task (Sweller, 1988). Utilising a dual-task strategy, Chandler and Sweller (1996) measured the cognitive load of participants studying either split-attention or integrated instructions (primary task). While studying the instructional materials, students were asked to recall letters that appeared on a second computer screen. As predicted, results from the study indicated students studying split-attention instructions did not perform as well on the
secondary tasks as students studying the integrated instructions. Chandler and Sweller (1996) concluded that conventional split-attention instructions were higher in extraneous cognitive load than integrated instructions (when intrinsic load was fixed).

There have been other cognitive load studies demonstrating the effectiveness of dual-task techniques to measure load during cognitive load studies (e.g., Marcus, Cooper & Sweller, 1996). However, it is argued that providing dual tasks can be intrusive to learning (Paas, 1992). Also, there is a body of evidence that suggests secondary task measures may not be as sensitive, unless they are delivered in the same modality as the primary task (as conducted by Chandler & Sweller, 1996). These issues highlight the limitation of the implementation of dual-task techniques, particularly in realistic educational settings.

The most promising source of cognitive load measures in terms of convenience, reliability and applicability are subjective, self-reported measures of mental load (Paas, 1992). Paas claimed the self-reporting scale is as effective as using more direct physiological measurements, such as measures of pupil dilation and heart rate, that seek to measure the construct of cognitive load. Overall efficiency ratings can be calculated by combining the performance on transfer items with their associated mental effort ratings. The acquisition of more/less efficient cognitive schemata is indicated by combinations of high /low performance and low/high mental effort. This is referred to as instructional efficiency (Paas & van Merriënboer, 1993). CLT is concerned with efficiency and, thus, the instructional efficiency measure provides an indication of this.
A recent critique of cognitive load measurement indicates that researchers need to exercise caution when using mental load scales (van Gog & Paas, 2008). The nine-point mental load scale (Paas, 1992) was originally designed for use in the test phase, so as to measure varied instructional effects on learning. However, since its introduction, the mental effort scale has been adapted and used in numerous CLT experiments, with many experiments implementing the mental load scale in both the learning phase and the test phase yielding interesting results but the validity of the results can be questioned (van Gog & Paas, 2008). Van Gog and Paas (2008) argue the adapted measure may be useful when the goal is to reduce extraneous load or enhance germane load. However, they claim studies that utilise the original scale tend to be more reliable measures of efficiency in learning. Because adaptations have varied when mental effort is obtained (learning phase as opposed to test phase), there are implications for the conclusions drawn regarding efficiency in learning. The adaptations have provided useful insight for poorly designed instructional formats (high extraneous load) but caution needs to be exercised when drawing conclusions from data where the instructional format seeks to stimulate mental effort (germane load) (van Gog & Paas, 2008).

2.4 CLT effects: a synthesis of the research
CLT research has generated a number of principles to guide the design of instructional material that provide optimal cognitive load management. The major design principles include: worked example effect, split-attention effect, modality effect, redundancy effect and expertise reversal effect. A synthesis of the research for each of these effects is explained below.
2.4.1 Worked example effect
The worked example effect is one of the first effects to be associated with the development of CLT. The development of the theory was concerned with how to design instruction that improved problem solving (with use of worked examples). Worked examples are problem statements that provide a step-by-step process to guide the novice on how to solve the problem and provide the correct answer. Following this path of guided instruction, the learner can develop schemas by developing an understanding of the structure underlying the problem.

Figure 2.3 shows a worked example for an algebraic equation where the learner is required to firstly study the worked example to find the answer and then attempt to solve a similar problem using the knowledge they have just acquired.

\[
\begin{align*}
    e(a + b) &= g \\
    \text{divide both sides by } e &\Rightarrow e(a + b)/e = g/e \\
    \text{cancel out } e \text{ top and bottom} &\Rightarrow a + b = g/e \\
    \text{subtract } b \text{ from both sides} &\Rightarrow a + b - b = g/e - b \\
    \text{cancel out } +b \text{ with } -b &\Rightarrow a = g/e - b
\end{align*}
\]

*Figure 2.3: Worked example involving geometry (Cooper & Sweller, 1987, p. 360)*

Conventional problem solving provides an unguided alternative, where the onus is on the learner to discover the best path to an answer. Considerable research has discussed the benefit of worked examples as opposed to conventional problem solving techniques for novice learners (Cooper & Sweller, 1987; Clark et al. 2006; Paas, 1992). Kalyuga et al.
(2003) emphasised that learners usually employ a means end strategy when they are unfamiliar with the problem at hand. Means ends analysis requires the learner to work backward from their desired goal. For a novice, who does not have sufficient understanding of the problem, it is the only strategy (other than trial and error) that is available to use. Means end analysis is thus not a learning strategy. Any learning that may occur is because efforts are directed toward a solution. As a result, important aspects of the problem may be overlooked (Sweller, 1999). Means ends analysis does not assist in the development of schemas and the process of automation and, as a result, imposes a heavy load on working memory (extraneous cognitive load). Providing learners with a worked example eliminates the means end search and directs attention toward a problem state and the moves necessary for completion of a task.

Sweller and Cooper (1985) and Cooper and Sweller (1987) demonstrated the worked example effect in a series of algebraic experiments where learners studied a series of worked examples. It was shown that the students who were provided with the worked examples were able to learn faster, and also made fewer errors than those students who were presented with conventional problems.

Worked examples need to be carefully constructed to avoid any unnecessary cognitive load (such as split-attention and redundancy), so they are not in themselves as demanding as means end analysis. Also, when learners possess a knowledge base sufficient for understanding, the use of worked examples may have a deleterious effect on the results (e.g., expertise reversal effect).
Much research has been conducted on the worked example effect, particularly in the field of mathematics, but, more recently, worked examples have been widely researched in a number of varied learning domains. Overall, the research conclusively demonstrates that using worked examples helps to decrease the amount of extraneous cognitive load, thus resulting in better learning (Sweller et al. 2011, pp. 99-108 provide a synthesis of research on the use of worked examples).

Whilst worked examples are most prominent for instructional materials associated with structured learning domains, such as mathematics and physics (Renkl & Atkinson, 2010), more recent research is focusing on the use of worked examples for ill-structured domains. Two recent examples include the use of worked examples in English literature (Kyun, Kalyuga, & Sweller, in press; and Oska, Kalyuga & Chandler, 2010)

2.4.2 Split-Attention Effect
The split-attention effect is an attentional phenomenon that has a direct effect upon learning. Split-attention refers to the processing of multiple sources of information to establish meaning (e.g., text and diagram). This process puts demands on working memory that are imposed purely because of the format of instruction. Integrated instructional formats, where related information sources are physically integrated, can be beneficial (for e.g., Figure 2.2 is easier to comprehend than Figure 2.1, the need to refer back to the text to extract meaning is not necessary, as the relevant information is included in Figure 2.2).
Integrated instructions reduce extraneous cognitive load, because there is no need to allocate resources to the mental integration of multiple sources of information. In other words, cognitive resources are not dedicated to activities unrelated to learning.

Means of reducing split attention also include the provision of signals and cues to focus attention on relevant aspects of information, such as the use of headings, bold, italics or verbal emphasis to draw attention to critical words or components presented in text or spoken (Clark et al., 2006).

The foundation research into split-attention was conducted by Tarmizi and Sweller (1988) who examined geometry problems with the use of worked examples. Tarmizi and Sweller were concerned that previous attempts to use worked examples in the mathematical domain, such as algebra (Cooper & Sweller, 1987), were highly effective but less effective for geometry problems. Further investigation led Tarmizi and Sweller (1988) to conclude that the separation of the diagram and the necessary solution path was placing additional strain on working memory. The requirement of mental integration appeared to increase cognitive load by having learners split their attention between the two sources of information. Tarmizi and Sweller (1988) demonstrated, by integrating the information contained in the worked examples (diagram and solution), that participants given the integrated information outperformed those who were presented with the original format (which required them to split their attention). Following this study a number of researchers continued to demonstrate the split-attention effect in different domains. Key studies that have examined the split-attention effect in different domains include: mathematics (Sweller et al., 1990), physics (Ward & Sweller, 1990); electrical
engineering (Chandler & Sweller, 1991); instruction of computer software (Kalyuga, Chandler & Sweller, 1999); instructional multimedia (Mayer 2001; Moreno & Mayer, 1998); and more recently, music instruction (Owens & Sweller, 2008). Some of these key studies are detailed below.

As mentioned previously, Chandler and Sweller’s (1991) use of electrical engineering diagrams within an industrial training setting demonstrated that when learners had access to integrated text, greater learning outcomes were achieved. A subsequent study that examined the use of audio narration of text to accompany a diagram of an electrical test lesson, (Tindall-Ford et al., 1997) found similar results, that is, the integrated format, using audio text and a diagram, significantly outperformed the split-attention format.

The split-attention effect within computer-based learning environments has also been researched. For example, Chandler and Sweller (1996) found that a computer software paper-based manual that physically integrated disparate information was more effective for learning the computer program than using a paper-based manual whilst interacting with the computer program. Moreno and Mayer (1998) examined split-attention effect within multimedia lessons. They conducted an experiment that examined three different versions of a lesson depicting how lightning forms. The integrated lesson (Figure 2.4) placed relevant text near its corresponding place in the diagram (on computer). The separated lesson had text in a block underneath the diagram of how lightning formed.
The third condition tested audio/visual learning by providing audio narration of the textual information presented on screen. Moreno and Mayer (1998) found the narrated version of the lesson produced the best learning outcomes. This was unlike the results found in the purely text-based experiments mentioned previously but also indicated the strength of the modality effect with narrated instruction. The split-attention effect was
replicated, as the integrated instruction condition outperformed the traditional format condition. Richard Mayer and colleagues have performed a number of experiments that collectively show that the integration of text and diagram leads to higher performance on post tests compared to spatially remote multimedia designs, where the content presented on computer screens displayed evidence of split attention (Ayres & Sweller, 2005). Mayer (2001) termed the effect ‘spatial contiguity’ due to the greater learning opportunities indicated by integration of information. Spatial contiguity is comparable with the term ‘split-attention’.

Other research that has investigated the split-attention effect within computer-based learning environments is the work reported by Cerpa (1998) and Cerpa, Chandler and Sweller (1996) where they demonstrated that integrated computer software training facilitated learning. The split-attention format included the use of a paper-based manual that explained how to use a computer software program. Cerpa (1998) emphasised the complexities involved in the search and match process required to manage split attention. His thesis examined computational models of the search and match process and how it imposes an extraneous cognitive load that impedes learning efforts. Cerpa (1998) found that this was especially true when the number of interacting elements was high. Thus he confirmed the findings of Sweller and Chandler (1994), that is, traditional paper-based manuals and use of a computer, splits limited cognitive resources and, thus, impedes learning. Integrated learning is a preferred delivery mode to avoid split-attention formats.

The research about the split-attention effect has consistently shown that the reduction of extraneous load occurs when learning materials are integrated, thus assisting more-
efficient processing. A key finding in the split-attention research is that integration is often best conducted before the learner attempts to learn the material. Chandler and Sweller (1991) indicated this was a necessary ‘preliminary to learning’. Chandler and Sweller (1991) considered integration of split sources of information occurs as a preliminary to learning because one needs to assign working memory resources to the search and match process before learning can occur.

A meta-analysis of the split-attention effect has shown the robustness of this effect (Ginns, 2006). Fifty research studies that comprising 37 spatial split-attention studies and 13 temporal split-attention studies, informed the meta-analysis, and the findings agreed that, across variety of learning domains and instructional formats, the split-attention effect is a sound and robust effect.

The research conducted to date on the split-attention effect has focussed on principles for how to design optimal instructional materials taking into account split-attention. There is, however, little if any research focused on how learners themselves could manage split-attention and, thus, extraneous load. This research study investigated a different direction for the use of CLT in education. The experiments conducted in this thesis examined whether instructing students to manage split-attention influenced their efficiency in learning new information.

2.4.3 Modality effect
The modality effect is inherently related to the structure of the dual-processing model (Baddeley & Hitch, 1974) and the claim that information can be processed more
efficiently using both auditory and visual pathways rather than a single modality. In the Baddeley model, working memory has two slave systems that are modality specific and assist working memory capacity, so it may be used more efficiently (the phonological loop and visuo-spatial sketchpad). As previously mentioned in chapter 1.5, and illustrated by Figure 1.2, the separate pathways are distinct entities within the working memory model.

The modality effect emphasises the ability to enhance WM by using the combined resources of the visual and auditory pathways, as opposed to a single modality. This is only the case when audio and visual sources of information rely on each other for understanding and element interactivity is high. The auditory section needs to be brief for it to be handled by WM. It allows the use of resources that cannot be involved with a single presentation mode. Understanding dual-modality instruction provides another mechanism by which instructors can handle the split-attention effect. For example, providing the textual material in an auditory format to students while examining the diagram visually may be far more effective than examining the information purely through the visual domain. This reduces the load on working memory and has been demonstrated by a number of researchers, including Mayer (1997), Kalyuga et al. (1999), Tindall-Ford et al. (1997) and Leahy, Chandler and Sweller (2003). Figure 2.4 provides an example of how a useful narrated version of text assisted learners forming schemas and learning the required information. The text provided in Figure 2.4 was provided in audio form and this improved performance on post-test measures because of the modality effect. By using both the visual and audio pathways working memory resources can be
directed toward schema formation. There are more resources available to the learner when two channels are utilised, compared to a single pathway or modality. Ginns (2005) conducted a meta-analysis of the modality effect, investigating 43 experiments that used a range of instructional materials, age groups and performance measures. The outcome of the meta-analysis provided support for the use of dual-mode presentation under the necessary conditions which were outlined earlier in the section. It also provided positive effects for the two primary moderators, element interactivity and the pacing of the presentation.

2.4.4 Redundancy effect
When multiple sources of information can be understood independently, it is best to use one source. The additional load on working memory makes the additional information redundant and can have an adverse effect on the learning goals. For example, Figure 2.5 highlights that information regarding airline safety is sufficiently explained via the pictures. Adding the text places unnecessary strain on working memory and, in turn, may confuse the learner. By including text, the information is considered redundant because it is self-explanatory via the diagram. Only one source is necessary to explain the content to the learner. By including both the instructional design overwhelms working memory unnecessarily.
Whether information is redundant also depends on the level of expertise of the learner. Novice learners may require more information (picture and accompanying text) to enhance their learning whereas this variety of information may be deemed redundant for the more experienced learner. As a result, integrated formats that are deemed effective for the novice could be ineffective for those who have an established schema for the information domain (‘experts’). Kalyuga et al., (1999) demonstrated the relationship between redundancy and split-attention electrical trainees. They found that the novice trainees learned best from the textual explanation that was embedded in the wiring diagrams (Figure 2.2). When the trainees were more experienced with the process, the effectiveness of the integrated diagram and text decreased while the effectiveness of the diagram-only condition increased. The trainees rated diagram only conditions as easier to
process when they were more experienced with the electrical wiring process (via subjective ratings). The integrated diagrams were essential for the novice but redundant for the more knowledgeable learner (Kalyuga et al., 1999). The results found in these experiments led to the emergence of the expertise reversal effect (explained below). More recent applications of the redundancy effect include exploration of redundancy in foreign language reading instruction (Diao, Chandler & Sweller, 2007). This research examined language comprehension in three varied instructional formats, listening with audio materials only, listening with full script and listening with subtitles. The listening with subtitles condition led to an improved understanding of the learning materials but poorer performance on a subsequent passage than those allocated to the listening with auditory materials only. Diao et al. (2007) found when the intention was learning to listen via audio, the use of a script with subtitles had a detrimental effect on the construction and automation of listening schemas.

In sum, if the information being relayed to the learner is self-explanatory via one source of information (visual/audio) it is best to just present one source to accommodate limitations of working memory capacity. The ‘less is more’ approach can reduce the chance of redundant information overwhelming cognitive resources (Clark et al., 2006).

2.4.5 Expertise reversal effect
The effectiveness of instructional methods is dependent upon the learner’s level of expertise. Techniques that are effective for a novice can lose their effectiveness, and even have negative learning impact, when used with more experienced learners. As the novice expands their knowledge in an area, the nature of the learning materials needs to be
adjusted accordingly. Similarly, the instruction that best supports the novice has the reverse effect on a more experienced learner.

As mentioned previously, Kalyuga et al. (1998) found that, as trainees developed expertise in an area, the text that accompanied diagrams became redundant. Learning from a diagram alone was more effective, and thus an expertise reversal phenomenon emerged. These results were replicated by another experiment (Kalyuga et al., 2000) with electrical trainees where the diagrams were explained by audio rather than text. As per their first experiment, Kalyuga et al. (2000) found the novice trainees benefited greatly from the integrated format of audio and diagram but as their expertise developed, the diagram only was sufficient due to the development of a schema that supported their learning. The reversal of efficiency occurred as the learners gained expertise.

A review of empirical research that led to the development of the expertise reversal effect is presented in Kalyuga et al. (2003). More recent support of the expertise reversal effect was demonstrated by Oksa, Kalyuga and Chandler (2010) for reading comprehension of Shakespearean text. Oksa et al. (2010) provided novices and experts with an elaborated Shakespearean text or original Shakespearean version. ‘Experts’ used in the experiments were scholars who taught Shakespeare at the university level, thus considered to have extensive knowledge of the subject matter. An example of elaborated Shakespearean text is included in Figure 2.6.
Figure 2.6: Elaborated version of Shakespeare’s Othello (Oksa et al., 2009, p. 157)

The elaborated version shown in Figure 2.6 was designed to assist comprehension of material by providing modern English explanations of Shakespeare by text (useful for novice). An example of original Shakespearean text is shown in Figure 2.7.

Figure 2.7: Original version of Shakespeare’s Othello (Oksa et al., 2009, p. 159)

The interpretation of Shakespearean text was integrated with the original text so subjects did not have to split attention from original text to supporting notes. The results indicated that novices benefited greatly from the elaborated text (Figure 2.6). However, experts
found the elaborations unhelpful and tended to favour the original text. For the experts, the elaborations were redundant. In the studies reported here care is taken not to confound split attention and redundancy by only involving participants who were novices within a learning domain. This ensured that the expertise reversal effect did not confound possible findings of the research.

The expertise reversal effect has prompted researchers such as Kalyuga (2006) to develop an assessment tool that provides educators with an indication of the learner’s level of expertise for an area. Kaluyga (2006) termed the assessment ‘rapid verification tests’ and they are largely used in multimedia environments. This highlights the need for instruction to be varied, according to the learner’s level of expertise in an area. The benefit of such a test is that online training can be adapted as the needs of the learner change, however, the adaptive testing requires a greater investment of resources than traditional designs that use a standard lesson for all learners.

2.5 Criticisms of CLT
Criticisms that have been raised about CLT relate mainly to how cognitive load is measured and the basic assumptions of CLT that intrinsic, extraneous and germane loads are additive (de Jong, 2010; Moreno, 2010). Through extensive empirical studies, CLT has evolved and will continue to evolve and, like any theory, is open to criticism. For example, the external validity of CLT research results have been questioned (de Jong, 2010) in terms of their applicability and relevance to realistic learning environments. This is an interesting observation given the large number of actual cognitive load studies that were conducted in school environments and workplace settings (some key examples
include: Chandler & Sweller, 1991; Kissane, Kalyuga, Chandler and Sweller, 2008; Kalyuga et al., 1999; Kalyuga et al., 2001; Tindall-Ford et al., 1997). Mayer (2010) has a more balanced view suggesting that both lab-based and realistic learning environments yield the most effective experimental educational research. As Mayer states “it is widely recognised that educational research is strengthened by multiple research methods so it is useful to conduct both lab-based and school-based studies” (Mayer, 2010, p. 144).

The research reported in this thesis utilised instructional materials that were actual learning materials within university courses and within students’ programs of study. This ensured that the instructions were both relevant to participants and realistic instructional materials.

Other criticisms directed at CLT include the interactions between the various categories of cognitive load (extraneous, intrinsic and germane). Again, as the theory has developed questions have been raised in relation to each source of load. Sweller (2010) agrees “much still remains to be done” (p.45) in relation to the expansion of knowledge regarding the specific instructional manipulations required of germane, intrinsic and extraneous load. Most of the CLT effects occur due to a reduction in extraneous load, allowing more efficient use of working memory resources. By increasing germane load, learning is enhanced. This basic formula has been challenged (de Jong, 2010; Moreno, 2010) and efforts to measure each source of load have commenced (de Leeuw & Mayer, 2008) but more research is required to produce an accurate result. Learning is a complex process and the reduction of one source of load does not necessarily equate to the rise of another source of load. Ongoing research may provide more definitive answers in relation
to the specifics of each source of load. The CLT research community agree that more research is the answer to the criticisms levelled at research that challenges the main premise for each source of load.

In summary, this section has provided an overview of CLT and some of the cognitive effects that have been generated by the research. As the theory has evolved, the accompanying research has demonstrated the depth of practical implications for instructional design and the need to consider human cognitive architecture. CLT illustrates ways to reduce unproductive sources of cognitive load and maximise aspects of cognitive load that lead to more efficient learning environments. The next section examines self-management of one’s cognition as another important step toward the development of cognitive skills.

2.6 Cognitive Load theory and the management of cognition

CLT has direct implication for the teaching of cognitive skills. Traditionally, research concerning CLT has focused on methods of instruction that decrease extraneous cognitive load that is not relevant to learning. The focus has been centred around instructor manipulated load where the instructor provides the necessary edits to ensure cognitive load is best managed. While this provides learners with their best chance of absorbing the information, they rely on the instructor to perform the task of minimising unnecessary cognitive load.

Current CLT research that relates to the management of cognition includes Kalyuga’s rapid assessment tool. Kalyuga (2006; 2010) is encouraging students to manage their own
cognitive load through the development of tools that assess the learner’s level of expertise within a content area. Through rapid assessment, the student chooses problems or worked examples depending on their level of expertise. Although there is some level of cognition management, it is still ‘instructor manipulated load’.

Becoming a self-directed learner is a complex task that is refined over the years, as students generate experience and knowledge relevant to their learning process. As mentioned in chapter 1, metacognition develops with age and experience. Self-directed learners use their metacognitive awareness to plan, develop and apply strategies that will make best use of the learning opportunities they are presented with. Self-reflection of their performance is also a feature. There are many students who struggle to manage their own learning and benefit from guidance regarding these skills (Joseph, 2006).

This section emphasises the importance of students becoming self-directed learners. It also emphasises the role educators have in directing learners to use their cognitive skills in a more effective manner. By encouraging students to reflect on their developing skills, independent learning will be more effective in the future when less support is readily available.

Early work in the field of human factors that relates to management of cognition comes from the field of aviation psychology. Raby and Wicks (1994) examined pilots’ decision making processes when under the demands of high workloads. Their study investigated when participants (pilots) performed a task and how they adapted their workloads when under high pressure. They revealed higher priority tasks were performed first and lower
priority tasks less often. By examining pilots' task management strategies further insight was gained that might shape the direction of training in cockpit management.

This research study examined how students can manage their own cognitive load. There is little research conducted with this focus and thus this thesis contributes to expanding the knowledge generated by CLT research. Instructor manipulated load is the primary area for existing CLT research. While strategies such as Kalyuga’s (2006) rapid assessment provide learners with some flexibility, there is still a reliance on the instructor manipulating the load. This thesis seeks to encourage students to manipulate the load themselves in an effort to become self-directed.

2.7 Summary
This chapter has provided a detailed explanation of CLT, explaining its origins, the cognitive effects related to the thesis and future directions of the field. The focus of CLT research to date has generally been focused on instructor manipulated cognitive load. This thesis investigates a new line of research, that is learner-manipulated instruction specifically intended for learners to self-manage cognitive load. Research in aviation psychology reveals examining workload management can provide insight for greater learning opportunities for future students.

The next chapter explains the empirical research conducted (a series of three experiments) that investigated the conditions to assist students manage examples of split attention for instructional materials. The final experiment in the study examined whether students can transfer the skill of managing split attention to new instructional materials.
Chapter 3

Introduction to experiments

3.1 Introduction

This chapter provides a rationale for the use of experimental design employed in this research and presents an overview of three empirical studies that comprise this thesis. The following three chapters explain the methodology and report the findings for each of the three experiments.

3.2 Rationale for experimental design

Experimental design is the ‘design of choice’ within the field of education where causal conclusions are warranted with regard to educational innovations (Mertens, 2005). The control of variables allows the researcher to claim that a certain variable had a specific effect. An experiment with well-specified hypotheses and random allocation to treatment groups provides the optimum environment to examine cause and effect relationships. CLT research has traditionally employed randomised controlled studies because of the robustness of this research methodology (Sweller et al., 2011).

The overall objective of this thesis was to examine how learners can self-manage cognitive load when presented with instructional materials with evident split-attention. The central hypothesis of this thesis was that learners who are guided on how to self-
manage cognitive load when presented with instructional materials with evident split-attention outperform learners who are presented with instructional materials with evident split-attention and not given guidance.

To conduct this investigation, an experimental design was employed, in which three experimental studies were conducted. Participants in each study were randomly allocated to different instructional groups and tested on their learning from differing instructional formats. Qualitative research methods were also utilised to gain further insight into how participants implemented the strategies they were exposed to in the instructional materials in the experiments. The research design for each of the three studies is explained below.

3.3 Overview of the three experimental studies

This thesis comprises three experimental studies that investigated how students could manage their own cognitive load when there was evidence of split-attention in the instructional materials.

In all three experiments, participants were randomly assigned to one of three conditions:

1. Conventional split-attention formatted instructional materials (Group 1 - split-attention)
2. Conventional format and given guidance on how to manage split-attention (Group 2 – self-managed cognitive load)
3. Integrated instructional materials (Group 3 – instructor-managed cognitive load).

The purpose of Experiment 1 was to, firstly, confirm the split-attention effect in the instructional materials, that is, test that condition 3 (Group 3) is superior to condition 1 (Group 1), and, secondly, test whether the specific guidance devised to assist learners to self-manage the split-attention effect (Group 2) led to better learning performance than the conventional split-attention condition (Group 1). Upon completion of the experiment, ‘think aloud protocols’ (Ericsson & Simon, 1993) were used to gain further insight about how participants engaged with the instructional materials.

Experiment 2 used the same instructional materials as Experiment 1 but the guidance provided to learners to self-manage the split-attention effect was revised (based on the findings from Experiment 1). The aim of Experiment 2 was to again confirm the split-attention effect in the instructional materials, and then test whether the revised guidance (Group 2) led to better learning performance than the conventional split-attention condition (Group 1).

Experiment 3 used the same instructional materials as Experiment 2 but was extended to include a transfer task that examined if participants (Group 2) could apply their knowledge of self-managing the split-attention effect to a new learning domain. There were two parts to the experiment. Part 1 replicated Experiment 2: in Part 2, participants in each of the three groups were presented with a set of new instructional materials with evident split-attention, and performance was measured similar to Part 1.
A summary of the research design for these three studies is outlined as follows:

Study 1: Confirm split-attention effect and test guidance to self-manage cognitive load
• Experiment 1
• Think aloud protocols

Study 2: Confirm split-attention effect and test revised guidance to self-manage cognitive load
• Pilot study
• Experiment 2

Study 3: Replicate Experiment 2 and test self-management of cognitive load skills in a transfer task
• Pilot study
• Experiment 3, Part 1 (replicate Experiment 2)
• Experiment 3, Part 2 (transfer task in new learning domain)

The subsequent three chapters explain the methodology and findings for each study.
Chapter 4

Study 1: Confirm split-attention effect and test guidance to self-manage cognitive load

4.1 Introduction

Study 1 comprised Experiment 1 and a follow-up study to Experiment 1 in the form of think aloud protocols. This chapter presents the methodology and results for Experiment 1 and the design and results of the think aloud protocols.

4.2 Experiment 1

The first experiment sought to confirm the existence of the split-attention effect within instructional materials developed specifically for this study, and investigate whether the guidance devised to assist students to self-manage the split-attention effect would lead to an increase in learning performance, as compared to students not provided with guidance to self-manage the split-attention effect when presented with conventional split-attention instructional materials. Participants were given instructional materials about an educational psychology theory: ‘Ecological systems theory’ (Vialle, Lysaght & Verenikina, 2008), which was a topic yet to be covered in a first-year university subject in which they were enrolled, and then asked to answer a series of questions related to the topic. Instructional materials were presented as conventional split-attention format (Group 1), conventional split-attention with guidance on how to self-manage split-
attention (Group 2) and in integrated format (Group 3). It was predicted that the integrated condition (Group 3) would lead to superior performance than the conventional split-attention condition (Group 1) due to the reduction in extraneous cognitive load imposed by integrated instructional formats (hypothesis 1). It was also expected that the conventional split-attention plus guidance condition (Group 2) would outperform Group 1 (conventional split-attention) in performance measures because the guidance about self-managing cognitive load would serve to reduce extraneous load (hypothesis 2).

4.2.1 Method

4.2.1.1 Participants and Design
One hundred and thirty-nine university students (106 females, 33 males, aged 17 - 45) volunteered to participate in the experiment. All participants were enrolled in a first-year education subject (EDFE101: Educational Foundations 1: Learning and Development), at the University of Wollongong that covered a variety of educational psychology theories and concepts. Six of the participants who completed the experiment were excluded from data analysis as they indicated prior knowledge of the information presented.

The experiment was conducted during Week 3 of a 13-week semester in 2009. The beginning of the semester was chosen to increase the likelihood that instructional materials had not been encountered by the participants.

Participants were randomly allocated to one of three conditions:

Group 1 - Split-attention formatted instructional materials. Participants allocated to Group 1 (n=44) received information about ‘Ecological systems theory’ in conventional
split-attention format presented on one A3 (420 x 297 mm) sheet of paper (see Appendix B). Conventional split-attention format required the participants to split their attention between the diagram and the written material, and then attempt to integrate the two sources of information to understand the diagram.

*Group 2 - Split-attention formatted instructional materials with guidance.* Participants in Group 2 (n=45) received identical delivery learning material as Group 1 but were given additional written guidance on how to integrate the material to enhance their learning (i.e., reduce the effect of split attention). The guidance consisted of three tips that were included in the instructional materials as text boxes, suggesting they number the systems, as well as sequence and highlight important information regarding ecological systems theory (see Appendix C).

*Group 3 – Integrated instructional materials.* Participants in Group 3 (n=44) were given the same information as the other two groups but in an integrated format (see Appendix D). This format was designed according to CLT principles on how to reduce split attention, that is, the diagram and text were physically integrated.

The study was conducted in seven tutorial classes (approximately 20 - 25 students in each class). Participants were randomly assigned to groups within each tutorial class. This was conducted by random allocation of the numbers 1 - 3 within the Excel for Windows program. As consent forms were gathered, subjects were randomly assigned to a group as per the computer-generated numbers. The design of Experiment 1 is illustrated in Figure 4.1.
4.2.1.2 Materials and Procedure

The experiment was conducted in the final 30 minutes of each of the seven tutorial classes. The participants were informed of the experiment the week prior to it being conducted. Participants completed a ‘pre-test’ (see Appendix A) to test for prior
knowledge and collect age and gender data. They were then given instructional materials to study for ten minutes. Upon completion of the study period, participants completed a post-test that comprised of questions to test their knowledge about the instructional material, mental effort ratings about studying the instructional materials and answering the questions and one open-ended question to solicit from participants what they did to help them learn the material (see Appendix E). Details of the materials and procedure are elaborated as follows.

The instructional material was a selected section from Chapter 11 of the EDFE101 textbook *Handbook on Child Development 2E* (Vialle, Lysaght & Verenikina, 2008, pp. 172 - 174). This content is a compulsory component of all first year education programs at the University of Wollongong. The material was to be covered in Week 11 of semester. The researcher identified that the presentation format of Chapter 11 that explained Urie Bronfenbrenner’s ‘Ecological systems theory’ was in the form of split attention. Thus, for purposes of this research, the same content about the ‘Ecological systems theory’, which comprised three pages in the textbook, was presented to each group but formatted as follows for each of the three conditions:

Group 1 – split attention instructional materials: The content was formatted in a similar way as in the textbook but presented on an A3 sheet of paper so that participants could view all the content from one sheet of paper).

Group 2 – split-attention instructional materials with guidance: Group 2 instructional materials were developed once the expert review for Group 3 instructional materials was
completed so that the guidance devised would assist participants to integrate the text with the diagram in a similar way as the integrated format. The explicit guidance was presented as text boxes that were overlayed on the split-attention instructional materials and participants were asked to perform three tasks to manage split attention: 1. link text to the diagram by circling paragraphs and drawing arrows to the relevant parts of the diagram; 2. number the levels of the theory in the diagram and associated text paragraphs in sequential order; and 3. Highlight words in the paragraphs and text in the diagram to emphasise important aspects of the theory (see Appendix C). The text boxes are illustrated in Figure 4.2.

Group 3 – integrated instructional materials: The content was reformatted to reduce split attention by integrating the text with the diagram. Developing the integrated material involved firstly reviewing the research concerning split attention (e.g., Ayres & Sweller, 2006; Chandler & Sweller, 1991; Clark et al., 2006; Cooper & Sweller, 1987; Mayer & Moreno, 1998; Tarmizi & Sweller, 1988) and reformatting the content presentation appropriately. One of the researcher’s supervisors (an international expert in CLT) reviewed the redesign of the instructional materials to ensure the removal of split attention.
All participants were asked to review their materials for ten minutes (learning phase).

Following the learning phase, the researcher handed out to all participants a post-test that was formatted as a single-sided, stapled, A4 booklet. The test consisted of recall, near transfer and far transfer items (explained below). Participants were given 15 minutes to complete the post-test items. All three sections were answered in sequence. When students had completed all items they folded the A3 instructional materials in half, which encased the post-test booklet and pre-test sheet, and waited for all to complete the post-test.
Recall items required participants to record all relevant aspects of the diagram (each component of ecological systems theory) and had a maximum score of 15. Examples of near transfer were: “What system impacts on the child due to changes in their environment over time?” and participants could achieve a maximum score of three. These items were simple in nature and usually a single word answer. Far transfer items included: “A homework centre in the local community has closed down due to lack of funding. What system does this correspond to?” and participants could achieve a maximum score of four. Far transfer items required greater understanding of the content in order the answer the question correctly. All post-test measures were considered dependent variables (recall, near transfer and far transfer).

Compliance was an additional measure included for analysis. Compliance was measured for participants allocated to Group 2 of the experiment and referred to participant use of the guidance provided in boxes surrounding the instructional materials. Participants in Group 2 were considered ‘compliant’ if they utilised at least one of the three strategies provided in the guidance.

Mental effort ratings were asked from participants at the completion of the learning phase, for example, “How much mental effort did you invest to learn this material?” and after each question in the post-test, for example, “How much mental effort did you invest to answer this question?” (see Appendix E). Mental effort ratings are considered a subjective measure of cognitive load that have been developed and tested during the past 20 years of CLT research (Paas, 1992). The rating provides an indication of the mental effort involved in a task. Subjective measures have been demonstrated to be as effective
in assessing mental load as physiological measures such as pupil dilation and heart beat patterns. Overall efficiency ratings can be calculated combining the performance on test items and their associated mental effort ratings (van Gog & Paas, 2008). An example of the mental effort rating scale used in Experiment 1 is shown in Figure 4.3.

**Question 1.** How much mental effort did you invest to learn this material? (please circle)

1------2-------3--------4-------5------6-------7-------8-------9

very, very low mental effort low mental effort moderate mental effort high mental effort very, very high mental effort

Figure 4.3: Mental effort rating scale used in Experiment 1

The mental effort rating scale developed by Paas (1992) was used, however, due to text formatting constraints in numbering each rating individually in a horizontal format, only 1, 3, 5, 7, 9 were labelled (as seen in Figure 4.3).

At the conclusion of the study, all participants were provided with information about self-management of split attention techniques (see Appendix F). Four participants from Group 1, and one from each of Groups 2 and 3 were excluded from data analysis as they indicated prior knowledge of the theory provided in the instructional materials.

**4.2.2 Results and Discussion**
A one-way analysis of variance (ANOVA) was conducted on test performance scores for each variable to explore any difference between the three groups. Means and standard deviations are included in Table 4.1.
The alpha level of 0.05 was used throughout the thesis unless otherwise specified as the criterion for determining statistical significance.

**Table 4.1: Experiment 1 Means and standard deviations (in parentheses) for test scores**

<table>
<thead>
<tr>
<th>Group</th>
<th>Performance Measures</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recall</td>
<td>Near Transfer</td>
<td>Far Transfer</td>
<td></td>
</tr>
<tr>
<td>1. Conventional (n=44)</td>
<td>7.26 (3.22)</td>
<td>1.59 (.99)</td>
<td>1.64 (1.28)</td>
<td></td>
</tr>
<tr>
<td>Percentage Correct</td>
<td>48.4</td>
<td>53</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>2. Conventional + Guidance (n=45)</td>
<td>8.13 (3.38)</td>
<td>1.76 (.96)</td>
<td>1.91 (1.26)</td>
<td></td>
</tr>
<tr>
<td>Percentage Correct</td>
<td>54.2</td>
<td>58.7</td>
<td>47.8</td>
<td></td>
</tr>
<tr>
<td>3. Integrated (n=44)</td>
<td>10.34 (3.05)</td>
<td>2.48 (.70)</td>
<td>2.52 (1.36)</td>
<td></td>
</tr>
<tr>
<td>Percentage Correct</td>
<td>68.9</td>
<td>82.7</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Total Score</td>
<td>/15</td>
<td>/3</td>
<td>/4</td>
<td></td>
</tr>
</tbody>
</table>

**4.2.2.1 Performance Measures**

Performance on the recall test differed significantly between the groups, $F(2, 133) = 10.69$. Effect size (partial $\eta^2$) 0.14. Post-hoc comparisons using Bonferroni contrasts revealed Group 3 recalled significantly more than Groups 1 and 2 (conventional instruction groups). There was no statistically significant difference between Group 1 and Group 2, despite a slightly higher mean for Group 2.

One-way ANOVA for near transfer questions demonstrated a significant effect of group on performance, $F(2, 133) = 12.26$, $MSe = .79$, $p < .05$. Effect size = 0.40. As with the recall task, post-hoc comparisons using Bonferroni contrasts indicated Group 3
outperformed both Groups 1 and 2 at a statistically significant level. No significant
difference was found between Groups 1 and 2.

One-way ANOVA for far transfer test items revealed a significant main effect of group,
\( F(2, 133) = 5.39, MSe = 1.68, p < .05 \). Effect size = 0.28. Bonferroni contrasts indicated
Group 3 outperformed Groups 1 and 2. There was no significant difference between
Groups 1 and 2.

The split-attention effect was replicated as the integrated format (Group 3) outperformed
the conventional format (Group 1) across all three test performance measures. Thus
hypothesis 1 was confirmed. The integrated format was shown to be superior to both a
conventional split-attention format and a split-attention (with guidance) format. Results
from the test performance measures did not indicate any significant differences between
the conventional split-attention and conventional split-attention (with guidance) groups.
Thus, there was no statistically significant evidence, based on performances, that the
conventional split-attention (with guidance) facilitated any self-management of cognitive
load. This is contrary to the hypothesised self-managed load effect. Thus hypothesis 2
was not confirmed.

4.2.2.2 Mental effort rating on instruction
A one-way ANOVA was conducted on the mental effort rating on instruction that
participants were asked to provide directly after the learning phase. Results indicated no
significant effect between groups \( F(2, 133) = 0.15 \). Thus, there was no significant
difference between groups for mental load ratings.
4.2.2.3 Efficiency Ratings

Efficiency scores (Kalyuga, 2009) were calculated by changing raw scores to z scores calculated using the mean and standard deviation for all participants, enabling use of the formula

\[ E = \frac{P - R}{\sqrt{2}} \]

where \( P \) = performance, \( R \) = rating (Kalyuga, 2009).

A one-way ANOVA was conducted on the efficiency ratings for recall, near transfer and far transfer. Efficiency ratings for recall did not yield a statistically significant difference between the groups \( F(2, 133) = 1.86, p = .16 \). Similarly there was no statistically significant difference between groups for far transfer efficiency scores \( F(2, 133) = 1.75 \). However, for near transfer efficiency ratings, there was a statistically significant difference between groups, \( F(2,133) = 7.08 \). There was a significant difference between Group 1 and Group 3 (\( p < .001 \)) and Group 1 and Group 2 (\( p = .028 \)).

Given the lack of differences between groups for mental effort ratings it is not surprising that efficiency ratings were not significant. The significance for near transfer efficiency is more likely to be due to test performance differences between groups than mental effort differences. Despite the overall lack of efficiency, it is worth noting that there was a significant efficiency difference favouring the conventional instruction group (with guidance) (Group 2) over the conventional instruction group (Group 1). This result suggests that the self-managed condition may have been a more efficient means of instruction than the conventional split-attention instruction.
Overall, the results for both mental load and efficiency measures did not produce any significant findings. Scores appeared to be similar amongst groups and thus no statistically significant results were achieved. This may be largely due to the scale not being an exact replica of the Paas (1992) scale. The issue of cognitive load measurement will be discussed at length during the discussion section of the thesis.

4.2.2.4 **Strategies reported by participants that helped them learn the material**

Qualitative analysis was conducted on the final item posed to participants; “When reading the information provided, please explain what you did to help you learn the material”. The responses for Group 2 were analysed to see if participants reported using the guidance provided. Group 1 and 3 did not receive guidance thus their responses were not analysed. Three participants did not provide an answer to this question. The qualitative analysis technique of segmenting responses into short phrases and then comparing the short phrases to see if they are similar or dissimilar was used to identify the themes (Young, 2005). A theme was identified if more than one participant wrote a similar response. For example, for the theme of ‘Learning the system in order/shortening words’ two of the participants were coded into this category for their response:

*Learn the systems in order from micro-meso-exo-macro. Get a little bit of an understanding on each system and tried to repeat it*   Participant 12

And from participant 34:

*I memorised the first few letters of the cycle....memorised what each cycle represented*
Overall, seven themes were identified from the responses provided by Group 2 (n=42).

The themes are outlined in Table 4.2.

Table 4.2: Seven strategies reported by participants

<table>
<thead>
<tr>
<th>Theme</th>
<th>No. of participants</th>
<th>Example comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highlighting/underlining key terms</td>
<td>13</td>
<td>“Highlighting and re-writing notes as I’m a visual learner” Participant 8</td>
</tr>
<tr>
<td>Re-reading the information</td>
<td>11</td>
<td>“Re read it” Participant 50</td>
</tr>
<tr>
<td>Learning the systems in order/shortening words</td>
<td>10</td>
<td>“Learn the systems in order from micro-meso-exo-macro. Get a little bit of an understanding on each system and tried to repeat it” Participant 12</td>
</tr>
<tr>
<td>Linking explanations to the diagram, drawing lines</td>
<td>9</td>
<td>“I was linking the explanations to the diagram” Participant 48</td>
</tr>
<tr>
<td>Acronyms, Mnemonics</td>
<td>5</td>
<td>“Remember MMEMC” Participant 51</td>
</tr>
<tr>
<td>Numbering the systems</td>
<td>5</td>
<td>“use the ideas in the boxes, such as numbering the systems” Participant 33</td>
</tr>
<tr>
<td>Summarising/making summary notes</td>
<td>2</td>
<td>“Wrote summary points for each paragraph” Participant 131</td>
</tr>
</tbody>
</table>
The most common response (13/42) indicated that highlighting important information or underlining key terms facilitated learning. These responses were similar to the guidance offered, thus important to identify as a theme. Eleven participants indicated re-reading the information assisted while ten claimed learning the components of ecological systems theory in sequential order helped. This response did not align with the guidance offered to the group.

Nine participants indicated linking explanations to diagrams and drawing lines assisted – this was aligned with the ‘guidance’ offered to participants who were randomly allocated to Group 2. This group were specifically instructed to perform this task in an effort to learn the material. The other ‘guidance’ offered to participants was numbering the systems and five participants claimed this assisted their learning.

Linking explanations to diagrams and drawing lines is critical to rendering split-attention instructions intelligible and, thus, a key skill for self-management of cognitive load. It was interesting that only nine of the total 45 students in Group 2 identified this theme as assisting them to learn the material. This result suggested that students did not fully utilise the guidance provided to them in the instructional materials.

4.2.2.5 Guidance compliance
Results of compliance measures indicated only 13 of the 45 participants (29%) allocated to Group 2 applied the guidance about how to self-manage split attention. Of those 13, only one participant completed all three tasks provided in the guidance. Three
participants completed two of the three tasks and nine participants completed one of the three tasks.

Poor level of compliance made it difficult to draw conclusions regarding the impact of the guidance, warranting further investigation of the reasons why participants in Group 2 did not comply with the guidance provided. Thus, a follow-up study in the form of think aloud protocols was conducted.

4.3 Think Aloud Protocols: Follow up to Experiment 1
Whilst Experiment 1 confirmed the existence of the split-attention effect, it did not show evidence for the self-management of cognitive load effect as there was no significant difference in performance between the conventional split-attention condition (Group 1) and conventional split-attention (with guidance) condition (Group 2) and in addition, there was a poor level of compliance of the guidance. Thus, further investigation about the usefulness of the guidance, was required in order to determine how the guidance could be revised to encourage a higher compliance rate.

The use of think aloud protocols was employed. Think-aloud data was collected by recording thoughts of participants during the learning phase (while they were studying the materials). This research method was developed by Ericsson and Simon (1993) to capture the content of short-term memory while completing a task, and is commonly used in CLT research. A recent example is the work by Oksa, Kalyuga and Chandler (2010) where think aloud protocols were used to ask ‘experts’ to give a verbal account of their thought processes while exposed to materials that were modified to assist ‘novice’ learners.
Think aloud protocols are appropriate when the aim is to capture what the subject/participant is actually doing and is most appropriate when exploring new concepts or phenomena, rather than simulating what research and supporting literature already demonstrates (Young, 2005). Considering that the self-management of cognitive load has not been previously investigated, the use of think aloud protocols was warranted, to provide the researcher with further insight as to why participants in Group 2 did not comply with the guidance provided and determine whether the nature of the guidance was useful. Additionally, comments regarding more effective means of presenting the guidance were welcomed.

4.3.1 Method

4.3.1.1 Participants
Four university students, who did not participate in Experiment 1, completed the think aloud protocols. All reported they had no prior knowledge of the theory presented in the instructional material (ecological systems theory).

4.3.1.2 Materials and Procedure
Prior to commencement participants were informed their ‘thoughts’ would be audio recorded. The participants were given the exact instructional materials provided to Group 2 of Experiment 1. Participants were asked to study the material for 10 minutes as if they were going to be examined on the content at the conclusion of the time. They were instructed to verbalise (‘think-aloud’) what they were doing with the information to make sense of it. At the conclusion of the learning phase, participants were then asked the following two questions:
1. How do you think you were making sense of the information?

2. What would you do to improve the layout or formatting of the information?

### 4.3.2 Results and Discussion

Results from the think-aloud protocols showed that only one of the four participants (25%) complied with the ‘guidance’ by writing on the instructional materials. This was a similar pattern in terms of compliance for Experiment 1 (25% in think aloud protocols versus 29% in Experiment 1). The think aloud protocols were transcribed and a similar analysis technique, as used for analysing the open-ended item in Experiment 1 (see section 4.2.2.4).

Participants verbalised a number of cognitive processes they used whilst reading and assimilating the information. Five themes were identified from the think aloud protocols. The dominant themes were included use of the diagram, linking diagram with text, ignoring the guidance and re-reading the material. Learning the systems in order was an identified cognitive tool used by two of the four participants in the study. All participants referred to use of diagram and linking diagram with text whilst engaging in learning. This procedure of search and match was present in all four think aloud protocols. The themes identified from the think aloud protocols are summarised in Table 4.3;

<table>
<thead>
<tr>
<th>Theme</th>
<th>No. of participants</th>
<th>Example from data</th>
</tr>
</thead>
</table>

*Table 4.3: Themes identified from think-aloud protocols*
1.1 The diagram assists understanding  

All 4 participants  

“…the diagram makes it easier to understand how these things fit in to the scope of what I’m supposed to read” Participant 1

1.2 Linking diagram with text to assist learning (search and match)  

All 4 participants  

“…So that if I link the text with the diagram, it helps to learn. Alright..”  

Participant 2

1.3 Ignored guidance  

Participant 1, 3, 4  

“…I read the info in the boxes but I did not use them…”  

Participant 3

1.4 Re-reading to facilitate meaning  

Participant 2, 3, 4  

“…I’m now re-reading the description of the various parts”  

Participant 3

1.5 Learning systems in order  

Participant 2, 4  

“micro, meso, I’m numbering them off on my fingers. Exo next one, macro, and cutting all over those is the chronosystem” Participant 2

Participants were asked to suggest improvements for the layout of the instructional materials. Overall, two suggestions were provided:

1. Make the guidance more explicit to ensure compliance
2. Separate the guidance from the content rather than embedding it within the instructional materials.

For example, participants suggested making the guidance more explicit by being clearer how the learner is to apply the guidance to the instructional materials. The following quotes show how two participants did not implement the guidance because it was considered more as ‘tips’ rather than specific tasks that needed to be completed:

*This is something to use help but I don’t know. If I only had 10 minutes I find it would be important to read it, to absorb it and the diagram. I’m not going to have time to circle things and number things because I have 10 minutes. If I have longer and I’ve absorbed it, then I would go through and do those little tips. It reminds me of what we say to our kids ‘read the instructions’. (Participant 1)*

*I ignored the command. I thought it was like help, and I felt I didn’t need help. I didn’t feel like I needed to physically link the text. I could just read and make that link mentally without putting pen across the paper. (Participant 3)*

Participant 4 justified their non-compliance by explaining that the guidance text boxes were a distraction:

*I didn’t see the benefit in the numbering thing. I definitely saw visually the headings each layer and how they relate to the diagram – I linked them visually but I didn’t go and*
draw a link or use a highlighter.... the boxes....they didn’t do much for me, they probably distracted me from the content more than anything.

In contrast, Participant 2 claimed:

*The hints you have break it down to manageable parts.*

The other main suggestion for improvement of the guidance was to separate the guidance from the instructional materials. One participant suggested that the guidance be presented at the outset before learning of content occurs.

These results provided insight into cognitive processes that may have occurred when participants in Experiment 1 attempted to make sense of the instructional materials. The participants’ two suggestions to improve the guidance concur with earlier cognitive load theory research work about the split-attention effect that referred to the cognitive process of performing the search and match integration tasks as ‘preliminaries to learning’ that it should be done before attempting to learn the material that is presented in a conventional split-attention format (Cerpa et al., 1996; Chandler & Sweller, 1991).

The results from the think aloud protocols enabled the researcher to redesign the guidance by providing more explicit instructions and separating the guidance from the instructional materials. The revised guidance was reviewed by an international CLT expert. This expert review supported the separation of the guidance from the instructional materials and recommended that the guidance should explicitly instruct how to integrate
the text with the diagram before the learner attempts to learn the content of the instructional materials.

Thus, after examination of the Experiment 1 data, analysis of the think aloud protocols and an expert review conducted on the revised guidance for Experiment 2, the aim of Experiment 2 was to test the revised guidance in terms of compliance and its influence on learning performance. Experiment 2 involved the use of the same instructional materials constructed for Experiment 1, altering one variable, the format of guidance provided to participants in Group 2.
Chapter 5

Study 2: Test revised guidance to self-manage cognitive load

5.1 Introduction
Study 2 comprised a pilot study and Experiment 2. The purpose of Experiment 2 was to examine if the revised guidance (informed by the findings from the think aloud protocols in Study 1) assisted students in the management of split attention.

5.2 Pilot Study
Prior to Experiment 2, a pilot was conducted to ensure compliance was more likely to occur with the revised instructional procedures (separation of the guidance) for those allocated to Group 2. The pilot also sought to examine the test material more closely through the use of think aloud protocols and a number of questions about the test material format.

5.2.1 Method
5.2.1.1 Participants
Two higher degree university students and one member of academic staff participated in the pilot study. All reported no prior knowledge of the theory presented in the instructional material.
5.2.1.2 Materials and procedure
Prior to commencement of the pilot, participants were informed their ‘thoughts’ would be audio recorded; all consented to the audio recording. The three participants were given the revised instructional materials that would be provided to Group 2 (split-attention instructional materials with guidance) in Experiment 2 (see Appendix G for the revised instructional materials used in the pilot). Participants were asked to study the material for ten minutes and they were going to be examined on content at the conclusion of the time. During the testing phase participants were instructed to verbalise (‘think aloud’) what they were doing with the information to make sense of it.

At the conclusion of the testing phase, participants were then asked the following questions:

1. Do you have any comments regarding the mental effort ratings? Did you find it [mental effort rating] was asked of you too many times?
2. What changes would you suggest of the testing materials?
3. Did you find the instructions easy to follow? Would you change them in any way?
4. Did performing the 3 tasks help you to learn?

5.2.2 Results and Discussion
All three participants complied with the three guidance tasks. One participant requested to reduce amount of mental effort ratings. All participants agreed providing an example of how the guidance was to be implemented was useful as verbally it is difficult to explain what wanting to do. For example, one participant said:
“It made it easier because as I was reading it I wasn’t quite sure what you meant and then I looked over and it was clear. I could see it. Once I did that I had already done 2 as it was in the example.” (Participant 1)

The other two participants made similar comments, that is, without the example it would have been difficult to comply with the guidance.

Regarding the format and wording of the guidance, participants offered suggestions to improve the wording of the guidance. Participant 2 advised: “When I read the first sentence I had to read it 3 times before I knew what I needed to do. So step by step what you need to do – no need for the explanation or have it last in brackets.” Participant 3 suggested a minor word change: “We are going in to it very, very blind and what does ‘integrating text’ mean, is it necessary? Maybe just the instruction”.

All participants agreed the three integration tasks stated in the guidance helped them to learn the material.

In summary, the findings from the pilot study included: 1. the need for more simplified instructions, and 2. include the provision of an example of each task to participants. The revised guidance for Group 2 materials (as result of the pilot) is illustrated in Figure 5.1
5.3 Experiment 2

The purpose of Experiment 2 was to examine if the revised guidance assisted in the self-management of split attention. The results of the think aloud protocols and expert review of the revised guidance in Study 1, followed by the pilot explained above, identified the need to both separate the self-management guidance from the instructional material and allow participants to read and apply the guidance before studying the instructional materials to ensure it was utilised. This would assist participants to understand how to self-manage cognitive load before attempting to learn the material – or in formal terms, engage in preliminaries to learning.

Experiment 2 had similar hypotheses as Experiment 1, that is, it was predicted that the integrated condition (Group 3) would outperform split-attention condition (Group 1) in
performance measures due to the reduction in extraneous cognitive load imposed by integrated instructional formats (hypothesis 1). It was also expected that due to improvements made to the guidance, the conventional split-attention plus guidance condition (Group 2) would outperform Group 1 (conventional split-attention) in performance measures because the guidance about self-managing cognitive load would serve to reduce extraneous load (hypothesis 2).

5.3.1 Method

5.3.1.1 Participants and Design
A total of 86 university students (61 females, 25 males, aged 21 - 44) volunteered to participate in Experiment 2. The mean age for participants was 26.31 (SD = 4.78). All participants were enrolled in a graduate teaching program (2009 cohort) at the University of Wollongong. This graduate degree enables students with an undergraduate degree in other disciplines to receive a degree that will enable them to teach in schools. As a result, they have not been previously exposed to education curriculum, thus naïve to the instructional material like the participants in Experiment 1. Participants who indicated prior knowledge of the theory were excluded from the study (n = 3). These participants were included in all phases of the experiment but their information was excluded from the analysis.

5.3.1.2 Materials and Procedure
Participants who volunteered for the study participated in this experiment in the final 30 minutes of a tutorial class. They had been informed of the study one week prior to it being conducted. All were informed of the general nature of the experiment and what would be required if they agreed to participate. Participants were randomly assigned to experimental groups using the same procedure as implemented in Experiment 1.
The instructional materials were identical to Experiment 1 for those allocated to Group 1 and Group 3. For Group 2, the learning materials were the same as in Experiment 1, however, the guidance was presented separately. As in Experiment 1, materials were a text-based account of the Ecological Systems Theory with a diagram representing layers of the theory described in the text. For Experiment 2, the self-management guidance was included on a separate A4 piece of paper attached/stapled to the front of the learning materials which were presented on an A3 sheet of paper as per Experiment 1. Participants were explicitly asked to implement the guidance (see Figure 5.1) before attempting to learn the materials.

All participants were given the learning materials on an A3 sheet of paper and asked to study the information for ten minutes. Participants were informed they would be examined on the content of the document directly after the ten minute learning phase. Participants answered the same items used in the testing phase of Experiment 1 – a series of questions measuring recall, near transfer and far transfer. This occurred directly after the learning phase. All performance-based questions were identical to the items used in Experiment 1, including a measure of compliance. Compliance included evidence documented on test materials that participants had adhered to the instructions regarding the use of split attention management guidance.

Based on the results of the pilot, the mental effort ratings were only asked of participants after the ten minute learning phase (instructional rating), recall and at the conclusion of
both near and far transfer items (see Appendix H for post-test materials of Experiment 2). The pilot suggested less mental effort ratings were preferred and considering Experiment 1 did not yield any significant results, it was decided to reduce the frequency of mental effort ratings. The same mental effort rating scale as in Experiment 1 (see Figure 4.3) was used.

5.3.2 Results and Discussion
One-way analysis of variance (ANOVA) was conducted on test performance scores to explore any difference between the three groups involved in Experiment 2. Means and standard deviations are included in Table 5.1.

<table>
<thead>
<tr>
<th>Group</th>
<th>Performance Measures</th>
<th>Recall</th>
<th>Near Transfer</th>
<th>Far Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Conventional (n = 27)</td>
<td>% Percentage correct</td>
<td>9.34 (3.67)</td>
<td>2.00 (.96)</td>
<td>1.78 (1.37)</td>
</tr>
<tr>
<td>2. Conventional + Guidance (n = 27)</td>
<td>% Percentage correct</td>
<td>10.11 (3.17)</td>
<td>2.54 (.64)</td>
<td>2.64 (1.34)</td>
</tr>
<tr>
<td>3. Integrated (n = 29)</td>
<td>% Percentage correct</td>
<td>11.81 (2.11)</td>
<td>2.38 (.73)</td>
<td>3.34 (.90)</td>
</tr>
<tr>
<td>Total Score</td>
<td>/15</td>
<td>/3</td>
<td>/4</td>
<td></td>
</tr>
</tbody>
</table>

5.3.2.1 Performance Measures
A one-way ANOVA indicated a significant main effect of group for the recall test items; $F(2, 83) = 4.91, MSe = 9.27, p < .05$. Effect size (partial $\eta^2$) 0.33. Post-hoc comparisons
using Bonferroni contrasts showed Group 3 performed significantly better on recall than Groups 1 and 2. There was no significant difference between Group 1 and Group 2, despite a slightly higher mean for the group with guidance (Group 2).

The one-way ANOVA for near transfer questions also demonstrated a significant main effect of group, $F(2, 83) = 3.38, MSe = .62, p < .05$. Effect size 0.28. Post-hoc comparisons using Bonferroni contrasts indicated Group 2 performed slightly, but not significantly, better than Group 3, however Group 2 performed significantly better than Group 1.

One–way ANOVA for the far transfer test items also revealed a significant main effect of group, $F(2, 83) = 11.64, MSe = 1.48, p < .05$, effect size 0.47. Results indicated Group 3 outperformed groups 1 and 2. Again Group 2 outperformed Group 1 at a statistically significant level.

5.3.2.2 Mental effort rating on instruction
A one-way ANOVA was conducted on the instructional rating (of mental effort) that participants were asked to provide directly after the learning phase. Results indicated no significant effect between groups $F(2, 83) = 0.28$. Thus, similar to Experiment 1, there was no significant difference between groups for mental load ratings.

5.3.2.3 Efficiency Ratings
A one-way ANOVA was conducted on the efficiency ratings for recall, near transfer and far transfer. Efficiency ratings for recall did not yield a statistically significant difference between the groups $F(2, 83) = 1.82, p = .17$. Similarly there was no statistically significant difference between groups for transfer efficiency scores $F(2, 82) = 1.42, p =$
Similar to the results in Experiment 1, the results for both mental load and efficiency measures in Experiment 2 did not produce any significant findings. Scores appeared to be similar amongst groups and, thus, no statistically significant results were achieved.

5.3.2.4 Guidance compliance
For measures of compliance within Group 2, 89% of participants (24/27) utilised the split attention guidance. This is a very notable difference from Experiment 1 when only 29% (13/45) complied with the instructions. Compliance ratings were recorded if participants utilised at least one of the three split-attention management tasks (as seen in Figure 5.1). The majority of compliant participants performed all three suggested tasks (number, link and highlight keywords).

The results from Experiment 2 confirmed both hypotheses in relation to split attention. Firstly, the split-attention effect was again replicated, with Group 3 outperforming group 1 in performance-based tasks. The second hypothesis was confirmed in Experiment 2, which indicated the provision of guidance (Group 2) in managing split-attention can allow participants to learn the material more efficiently.

The additional guidance offered to the conventional instructions improved performance across all three measures. For recall, the difference was not statistically significant but for both near and far transfer items Group 2 outperformed group 1. The additional guidance offered to the conventional instructions appears to have improved learning efforts for participants allocated to Group 2.
Chapter 6

Study 3: Replicate experiment 2 and test cognitive load self-management skills in a transfer task

6.1 Introduction

Study 3 comprised a pilot study and Experiment 3. The final experiment sought to measure the transferability of the split-attention management skills. The results from Experiment 2 showed that providing guidance on how to self-manage split-attention instructional materials was beneficial, as the conventional split-attention plus guidance condition (Group 2) outperformed the conventional split-attention condition (Group 1) on transfer items. Experiment 3 sought to explore whether this skill might be transferred to a new learning domain. Providing participants with a new set of materials with evident split-attention would test whether they would be able to transfer the skill to a new learning domain, thus providing evidence for the self-managed cognitive load effect.

Experiment 3 was structured in two parts. The aim of Part 1 was to replicate the split-attention effect (as evident in both Experiments 1 and 2) and the aim of Part 2 was to test whether the self-management skills acquired by Group 2 would be transferable to a new learning domain.

Part 1 of Experiment 3 had similar hypotheses as Experiment 2, that is, it was predicted that the integrated condition (Group 3) would outperform split-attention condition (Group 1) in performance measures due to the reduction in extraneous cognitive load imposed by
integrated instructional formats (hypothesis 1). It was also expected that the conventional split-attention plus guidance condition (Group 2) would outperform Group 1 (conventional split-attention) in performance measures because the guidance about self-managing cognitive load would serve to reduce extraneous load (hypothesis 2).

For Part 2 of Experiment 3, it was hypothesised that participants allocated to Group 2 in Part 1 of Experiment 3 would transfer self-management skills to the new split-attention instructional materials, leading to a reduction in extraneous load, and thus outperform Group 1 (hypothesis 2). If the skills of split-attention management (circling, numbering and highlighting key terms) were transferred, it was hypothesised that these skills would enhance performance on post-test measures.

6.2 Pilot Study

6.2.1 Method

6.2.1.1 Participants
Two higher degree university students and one member of academic staff, all female, participated in the pilot study. The two university students reported no prior knowledge of the theory presented in the instructional material. The academic staff member recalled one of the theorist’s names in regard to a different application of knowledge. She claimed to have no knowledge of the specific theory used.

6.2.1.2 Materials and procedure
Prior to commencement of the pilot, participants were asked to complete a consent form and were given a brief description of what would be required of them during the pilot
They were asked to consent to a brief interview after completion of the experiment, which was audio recorded; all three consented to the outlined procedures.

Participants were given the exact instructional materials that would be provided to Group 2 for both Part 1 and Part 3 of Experiment 3. This included the same instructional materials and guidance provided Group 2 in Experiment 2 (ecological systems theory) plus an additional learning task whereby a new set of split-attention instructional materials were presented (Kohlberg’s stages of morality theory, see Appendix I).

Participants were given ten minutes to study the materials before questions relating to the content were asked. Then participants were given another 10 minutes to examine a further set of learning materials, followed by a post-test. During the second component of the testing phase participants were asked to comment on the second set of instructional materials, asking specifically if they used the split-attention management principles outlined in the first set of instructional materials (numbering systems, linking text with diagram and highlighting – refer to Figure 5.1).

Participants were then audio recorded for their response to the following questions;

1. Any comments regarding the materials or the experiment in general?
2. What changes might you suggest?
3. Was it cognitively demanding?
4. Did you find the instructions easy to follow? Would you change them in any way?
5. Do you think performing the three tasks helped you to learn?
6. Did you perform the three tasks for Kohlberg’s stages of morality theory?


6.2.2 Results and Discussion

General comments (answers to Question 1) recorded by the two university students were that they needed additional time to study the first set of materials. Both agreed the three tasks required in the first set of instructional materials used valuable study time that they felt may have impeded their performance. As a result, they were reluctant to perform all three tasks for the second set of instructional materials as they felt it would consume valuable ‘study time’. Interestingly, the member of academic staff commented there was sufficient time allocated to learn the content of instructional materials and she felt that less time was required for the second set of instructional materials.

Changes (Question 2) suggested by all participants included an explicit reminder to return to the materials to continue studying after completing the three allocated tasks (number, link text with diagram, highlight). One participant commented the tasks distracted her from the initial instruction: ‘study this material for ten minutes’.

The academic staff member suggested including a line space between each of the 3 instructions (number, link text with diagram, highlight) as the information was in close proximity to each other, appearing congested and thus difficult to return to the materials for the next task.

When questioned if the task was cognitively demanding, one commented it was, while the other two claimed it was tolerable. The participant who claimed it was difficult said: “I had difficulty forgetting the first set of instructional materials before moving on to the second one”. In the classroom application of the experiment this may be lessened by the
time it takes to hand out the second set of materials, and a brief discussion the requirements of the second task.

Question 4 was largely addressed by the first and second questions, as participants were willing to comment on the instructional tasks in general. Participant 3 claimed: “it was similar to the techniques I use to study information...I draw all over my page. I don’t do it first because I don’t know why I do it. At first I found it artificial (performing three tasks) but then I see it helped me.....I definitely see it helping those who don’t have skills”.

The final question asked if participants transferred the three tasks from the first set of materials to the second. All three participants commented that they found it useful to number the stages and highlight important information. One commented she was going to link text with diagram but chose to use her time learning the information. Another mentioned it would make the materials ‘messy’ so she did not chose to link text with diagram, whereas the third participant commented: “I definitely numbered and highlighted but also asked questions of myself and explained it, which is how I learn...If this was bigger (the diagram) I would have written more near it but it would be crammed”.

The results of the pilot indicated it was essential to place a reminder at the end of the instructions to return to learning the material. This was amended on the guidance (see Figure 6.1). The pilot also indicated that the combined learning tasks were achievable by participants.
Completing the instructions below will help you to learn the information presented on the A3 page more effectively by making efficient use of your working memory.

1. Before you read the information in detail, match the text with the diagram by drawing a circle around each paragraph on the right hand of the page (which explains each system, eg., Microsystem, Mesosystem, Exosystem, Macrosystem, and Chronosystem) and drawing an arrow to link it to its corresponding place in the diagram. The first one has been done for you.

2. Then, number each system in sequence (eg., 1. Microsystem, 2. Exosystem, 3. Mesosystem, etc) on both the diagram and the text. The first one has been done for you.

3. While you are reading, highlight or underline key words that relate the information with the diagram (one has been done for you).

Now go back and study the content for the remainder of the time…..

Figure 6.1: Revised guidance for experiment 3

6.3 Experiment 3

6.3.1 Method

6.3.1.1 Participants and Design
In total 85 university students (61 females, 24 males, aged 20 - 56) volunteered to participate in Experiment 3. The mean age for participants was 26.64 ($SD = 7.325$). All participants were enrolled in a graduate teaching program (2010 cohort) at the University of Wollongong as in Experiment 2. Similar to Experiment 2, participants were unlikely to have been previously exposed to education curriculum content thus being naïve to the instructional material. Participants who indicated prior knowledge of the theory were excluded from the analysis ($n = 4$).
6.3.1.2 Materials and Procedure
Participants who volunteered for the study were exposed to the experiment at the commencement of a tutorial class. They had been informed of the study one week prior to it being conducted. All were informed of the general nature of the experiment and what would be required if they agreed to participate. Participants were randomly assigned to one of the three experimental groups.

For Experiment 3, Part 1, the instructional materials were identical to Experiment 2, other than the slight revision to guidance indicated by Figure 6.1. All participants were given the learning materials on an A3 sheet of paper and asked to study the information for ten minutes. Participants were informed they would be examined on the content of the document directly after the ten minute learning phase.

Participants answered the same items used in the testing phase of Experiments 1 and 2 – a series of questions measuring recall, near transfer and far transfer. This occurred directly after the learning phase. All performance-based questions were identical to the items used in experiments 1 and 2, including a measure of compliance. Compliance included evidence documented on test materials that participants had adhered to the instructions regarding the use of split-attention management guidance. The same mental effort rating scale as in Experiment 2 (see Figure 4.3) was used.

Part 2 of Experiment 2 proceeded directly after Part 1. All participants in each of the three conditions were presented with a completely new set of instructional materials that demonstrated evidence of split attention. Again participants were asked to study the
material for 10 minutes, then answer questions that relate to the content (see Appendix I for the new set of instructional materials and see Appendix J for the Part 2 post-test).

6.3.2 Results and Discussion: Experiment 3, Part 1
One-way analysis of variance (ANOVA) was conducted on test performance scores to explore any difference between the three groups involved in Experiment 3, Part 1. Means and standard deviations are included in Table 6.1.

Table 6.1: Experiment 3, Part 1 Means and standard deviations (in parentheses) for test scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Performance Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recall</td>
</tr>
<tr>
<td>1. Conventional (n=29)</td>
<td>9.05 (4.09)</td>
</tr>
<tr>
<td>Percentage correct</td>
<td>60.4</td>
</tr>
<tr>
<td>2. Conventional + Guidance</td>
<td>10.23 (3.67)</td>
</tr>
<tr>
<td>(n=28)</td>
<td>68.2</td>
</tr>
<tr>
<td>3. Integrated (n=24)</td>
<td>12.58 (2.87)</td>
</tr>
<tr>
<td>Percentage correct</td>
<td>83.9</td>
</tr>
<tr>
<td>Total Score</td>
<td>/15</td>
</tr>
</tbody>
</table>

6.3.2.1 Performance Measures, Part 1
One-way ANOVA indicated a significant main effect of group for recall test items, $F(2, 81) = 6.37, MSe = 13.10, p < .05$. Effect size (partial $\eta^2$) 0.37. Post-hoc comparisons
indicated that Group 3 recalled significantly more items than Groups 1 and 2, which did not differ from each other.

The one-way ANOVA for near transfer questions also demonstrated a significant main effect, \( F(2, 81) = 3.38, MSe = .62, p < .05, \) effect size = 0.39. Post-hoc comparisons using Bonferroni contrasts indicated Group 1 performed significantly more poorly than Group 2 or Group 3, which did not differ from each other.

One-way ANOVA for the far transfer test items also revealed a significant main effect, \( F(2, 81) = 11.64, MSe = 1.48, p < .05, \) effect size = 0.68. Results indicated Group 3 outperformed Groups 1 and 2. Again Group 2 outperformed Group 1 at a statistically significant level.

The results for recall, near transfer and far transfer for Part 1 of Experiment 3 was almost identical to the results in Experiment 2. This was expected as it was a repeat of Experiment 2, with a similar number of participants used for the study. Again compliance measures were recorded to ensure participants implemented the guidance provided.

6.3.2.2 Mental effort rating on instruction, Part 1
A one-way ANOVA was conducted on the instructional rating (of mental effort) that participants were asked to provide directly after the learning phase. Results indicated no significant effect between groups, \( F(2, 81) = 1.23. \) Thus, similar to experiments 1 and 2, there was no significant difference between groups for mental load ratings, \( p = .29. \)
6.3.2.3 Efficiency Ratings, Part 1
A one-way ANOVA was conducted on the efficiency ratings for recall, near transfer and far transfer. Again, results indicated no significant difference between groups $F(2,81) = 1.71$. Thus, mental load ratings did not yield significant differences.

6.3.2.4 Guidance compliance, Part 1
For measures of compliance within Group 2, 89% of participants (25/28) utilised the split-attention management guidance. As with experiments 1 and 2, compliance was measured by evidence of using the suggested guidance regarding management of split attention. Compliant ratings were recorded if participants utilised at least one of the two split-attention management tasks. The majority of compliant participants (18/25) performed all three suggested tasks.

The results from Experiment 3, Part 1 confirmed both hypotheses in relation to split attention. The split attention effect was again replicated, with Group 3 outperforming conventional groups in performance-based tasks. The second hypothesis was confirmed, which indicated the provision of guidance in managing split-attention can help participants to learn instructional material more efficiently.

The additional guidance offered to the conventional instructions improved performance across all three measures. For recall, the difference was not statistically significant but for both near and far transfer items Group 2 outperformed Group 1. This leads to the conclusion that the additional instructions provided to Group 2 in the form of guidance allowed learners to actively self-manage extraneous load by conducting the three tasks
considered ‘preliminaries to learning’ before attempting to study the experimental materials.

6.3.3 Results and Discussion: Experiment 3, Part 2
One-way analysis of variance (ANOVA) was conducted on test performance scores to explore any difference between the three groups involved in Experiment 3, Part 2. Means and standard deviations are included in Table 6.2.

Table 6.2: Experiment 3, Part 2 - Means and standard deviations (in parentheses) for test scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Performance Measures</th>
<th>Recall</th>
<th>Near Transfer</th>
<th>Far Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Conventional (n=29)</td>
<td>Percentage correct</td>
<td>7.21 (2.26)</td>
<td>2.34 (1.59)</td>
<td>1.86 (1.46)</td>
</tr>
<tr>
<td></td>
<td>Percentage correct</td>
<td>72.1</td>
<td>46.8</td>
<td>46.5</td>
</tr>
<tr>
<td>2. Conventional + Guidance (n=28)</td>
<td>Percentage correct</td>
<td>8.64 (1.52)</td>
<td>3.75 (1.24)</td>
<td>3.25 (1.32)</td>
</tr>
<tr>
<td></td>
<td>Percentage correct</td>
<td>86.4</td>
<td>75.0</td>
<td>81.3</td>
</tr>
<tr>
<td>3. Integrated (n=24)</td>
<td>Percentage correct</td>
<td>8.12 (1.78)</td>
<td>2.75 (1.26)</td>
<td>3.42 (.78)</td>
</tr>
<tr>
<td></td>
<td>Percentage correct</td>
<td>81.2</td>
<td>55.0</td>
<td>85.5</td>
</tr>
</tbody>
</table>

Total Score /10 /4 /4

6.3.3.1 Performance Measures, Part 2
One-way ANOVA indicated a significant main effect for recall test items, $F(2, 81) = 4.29$, $MSe = 3.51$, $p < .05$, effect size (partial $\eta^2$) = 0.32. Post-hoc comparisons using Bonferroni contrasts indicated that Group 2 recalled more items than groups 1 and 3.
The one-way ANOVA for near transfer questions also demonstrated a significant main effect, $F(2, 81) = 7.76, MSe = 1.90, p < .05$. Effect size 0.41. Post-hoc comparisons using Bonferroni contrasts indicated Group 2 outperformed both Group 1 and Group 3. Both comparisons were statistically significant.

One-way ANOVA for the far transfer test items again revealed a significant main effect, $F(2, 81) = 13.04, MSe = 1.55, p < .05$, effect size 0.50. Results indicated Group 3 and Group 2 outperformed Group 1 at a statistically significant level.

Some concern is warranted in regard to ceiling effects with the far transfer items. The majority of participants scored well on the far transfer item and closer examination of the data revealed a number of participants allocated to Group 1 did not even attempt to answer the far transfer items which, in turn, reduced the average for Group 1. In total, 7 of the 29 participants allocated to Group 1 did not attempt to answer the question. Three participants from Group 2 also failed to answer the far transfer item. If these ten participants were removed, the average score achieved by the remaining participants was 3.08 out of a maximum score of 4. In total, 38 participants scored 4 (maximum). Thus it appears to be a problem with the transfer item itself which is meant to be a more difficult question in relation to near transfer and basic recall items.

Like experiments 1 and 2, there was a 15-minute time limit to answer all questions in sequence. When students had completed all items they were asked to place their answer booklet inside the test materials and await further instruction. This meant that students could go between test questions, back to sections as they answered each item.
6.3.3.2 Mental effort rating on instruction, Part 2
A one-way ANOVA was conducted on the instructional rating (of mental effort) that participants were asked to provide directly after the learning phase. Results indicated no significant effect between groups $F(2, 81) = 1.23$. Thus, as in experiments 1 and 2, there were no significant differences between groups for mental load ratings.

6.3.3.3 Efficiency Ratings, Part 2
A one-way ANOVA was conducted on the combined efficiency ratings for recall, near transfer and far transfer. Again, efficiency ratings for recall did not yield a statistically significant difference between the groups $F(2, 81) = 1.71, p = .57$. As with the results of experiments 1 and 2, the results for both mental load and efficiency measures did not produce any significant findings. Scores appeared to be similar amongst groups and, thus, no statistically significant results were achieved.

6.3.3.4 Guidance compliance, Part 2
An examination of the experimental materials for those allocated to Group 2 occurred. The results indicated a number of participants repeated the instructions given ($n = 13$) in Part 1 of the experiment. The most common response was underlining key words, with only a few numbering ($n = 5$) and two linked the text with diagram.

6.3.3.5 Transfer skills of split attention management
Participants allocated to Group 2 were given an additional item at the post-test phase. They were asked if they transferred any of the skills they were asked to perform (number, highlight, link text with diagram) to Part 2 of the experiment. They were not explicitly directed to perform the split attention management tasks (as in Part 1), thus, the question
was exploratory and intended to examine if students were aware of transferring any skill that may have been acquired in Part 1.

A total of 15 participants indicated they did not perform the tasks, however, analysis of their test materials showed some evidence that they did, in fact, highlight, underline or link text with diagram (but to a lesser degree than those who responded ‘yes’). Many commented that they did not consider the three tasks would assist their learning efforts at all. For example, Participant 24 commented “No, it did not assist my learning in any way” or #30 “No, I didn’t feel they helped me”. However, this participant did show evidence of highlighting, numbering and linking of information.

For those participants who indicated yes, they transferred the skill, many additionally commented that they did not feel it helped them to learn the material. For example Participant 50 “Yes, but I didn’t find it useful”. This participant also showed evidence of highlighting and linking.

It is interesting that those allocated to Group 2 were unaware of the advantage they had over Groups 1 and 3 in relation to exposure of techniques that could potentially reduce extraneous cognitive load presented by the materials. Many did not consider the tasks useful to perform and some even commented that they performed the tasks ‘mentally’ rather than drawing on their instructional materials. This provided the researcher with insight into their ability to recognise whether performing preliminaries to learning was in fact beneficial to their learning efforts.
The results for Part 2 of Experiment 3 did demonstrate that those allocated to Group 2 were at an advantage to Groups 1 and 3, because they were exposed to self-management of split attention techniques. This, in turn, provided an ability to reduce extraneous load imposed by the need to search and match between text and diagram to make sense of the materials. Although participants in Group 2 did not self-report the techniques as useful, the performance measures indicated otherwise.

An important issue related to the design of Experiment 3, Part 2 was the nature of the far transfer test items. The items did not appear to be true far transfer items and thus significant differences between groups were not apparent, as was the case for near transfer items. This is further discussed in the next chapter.
Chapter 7
Discussion

7.1 Summary of findings
This thesis is comprised of three studies that examined whether the provision of guidance to students could facilitate self-management of their cognitive load when presented with split attention instructional materials. The results of the three studies in this thesis demonstrate potential for students to self-manage cognitive load in split attention learning environments.

Research on CLT has primarily focussed on providing empirical evidence for the benefit of designing materials that complement human cognitive architecture. The research has provided much support for the need to consider the varied instructional effects during construction of learning materials. Despite the depth of research, examples of poorly designed instructions continue to plague textbooks, web design, Power Point presentations and the array of media presented to students studying at university.

The experiments documented in this thesis were designed to examine the ability of students to self-manage split attention (with instructional materials) when provided with specific ‘guidance’ on how to do so. This is the first line of research that has demonstrated that teaching students how to manage cognitive load in a particular context can benefit their learning. The use of pilot studies, think aloud protocols, ‘compliance’ and qualitative comments were all utilised to make sense of the data and complement the three experiments included in this thesis.
Experiment 1 investigated whether teaching skills that assist students to manage split attention was useful when learning new information. In the first instance, it needed to establish evidence of split attention with the learning material.

In relation to CLT, it was hypothesised that participants allocated to the integrated group (Group 3) (where split attention was managed) would outperform those allocated to a traditional format (where evidence of a requirement to split attention was present) (Group 1). This hypothesis was based on research investigating the split-attention effect within CLT (Chandler & Sweller, 1991). Research has demonstrated it is important to avoid formats that require the learner to divide their attention between multiple sources of information in order to make sense of the material. When a learner is required to divide their attention between multiple sources of information, cognitive load is increased by the need to integrate the sources of information to extract meaning, resulting in poorer learning. Thus, participants allocated to the integrated group were expected to perform better than the traditional group because extraneous load was managed, and more resources were available for learning.

The integrated group outperformed the traditional format group, thus demonstrating a split-attention effect. The second hypothesis was not confirmed as the guidance provided to the second group, who were also provided the traditional format, was not utilised in the manner intended (an example of poor compliance). Participants did not appear to use the guidance to manage split-attention and thus, Group 2 did not differentiate from Group 1 for any of the performance measures. Subsequently, a follow up study utilising think
aloud protocols, showed the design of the guidance was problematic. The design of the learning materials for Group 2 needed to be revised to enable a more accurate test of the hypotheses. The original idea was to integrate the guidance with the content but the feedback from the think aloud study showed that participants preferred the content and guidance to be presented in a separate format.

Use of think aloud protocols that specifically targeted reasons for not complying with the self-management guidance offered to Group 2 participants provided useful insight for the difficulties inherent within the design of the first experiment. The think aloud protocols revealed participants did not use the guidance because they thought it was optional, would not benefit their learning or was simply a distraction. The insight offered, shaped the direction of guidance being offered to participants for the second experiment. Learning materials were revised and expert reviewers with extensive research experience in CLT provided advice regarding the structure of the second experiment. This restructure led to the ‘guidance’ for managing split attention, being delivered as a preliminary to a learning task rather than an option during the learning phase.

It is important to note that following the guidance requires participants to perform an additional task. While cognitive load is already high (due to split attention) the extraneous load imposed by performing the task would expect poor performance by Group 2 because of the additional load. Although following guidance was extraneous, the results of experiments 2 and 3 indicate performing the additional tasks influenced participant’s learning in a positive manner.
The results of the second experiment revealed that asking participants to self-manage split attention before attempting to learn the materials improved their performance in relation to test items. Participants who learned the exact material but were not offered split attention management guidance performed poorly on all performance measures than those offered advice. The split attention effect was again replicated, as participants allocated to the integrated group outperformed the traditional-format group. In short, the second experiment suggested students can be instructed on methods to self-manage split attention, which has not previously been examined within the CLT research.

The third experiment sought to replicate the findings of Experiment 2 but also extend the research by examining whether participants would be able to transfer the skill of self-managing split attention to completely new instructions from a novel learning domain. Replication of the results achieved in Experiment 2 occurred. Group 3 outperformed Group 1, indicating the split-attention effect. Asking participants assigned to Group 2 to self-manage split attention before attempting to learn the materials improved their performance in relation to test items. Participants who learned the same material but were not offered split-attention management guidance performed more poorly than those offered advice across all performance measures.

The important aspect of Experiment 3 was Part 2. Part 2 of Experiment 3 required participants to study another novel theory where a diagram was present and evidence of split attention (Appendix I). The research intended to examine whether the skills acquired (by Group 2) in the first part of Experiment 3 would transfer to a novel task. The results showed that this indeed occurred, as Group 2 outperformed both Group 1 and Group 3.
This indicated the skills were transferred to the second phase of the experiment and this was evidenced by the fact that they provided evidence of managing split attention on their learning materials (number, sequence and highlight important information). Interesting to note was the response to a question at the completion of the experiment. Participants were asked if they transferred skills and they did not appear to realise that they did. Many disregarded the usefulness of guidance despite it clearly improving performance on test items. Sometimes students are unable to verbalise how they are learning. This was demonstrated in Sweller and Chandler’s (1994) research that examined the use of a computer program online versus a printed manual. Most students are also unaware of their learning styles and if left to their own devices they are unlikely to learn new strategies (Merrill, 2000).

The results of the combined studies of the thesis indicate four key findings. They are now going to be discussed.

**7.2 Key findings:**

1. **The robustness of the split-attention effect**

   This key finding was demonstrated by analysing the ‘Integrated’ versus ‘Non-integrated (conventional split attention)’ groups (i.e., Group 3 versus Group 1).

   Across the three experiments it was found that when split attention was managed (integrated) for participants, they consistently outperformed those allocated to non-integrated materials. Significant results were found for Recall, near transfer and far transfer in Experiment 1. Effect sizes are demonstrated in table 7.1. For experiment 2,
statistically significant results were produced for recall and far transfer. For Experiment 3, statistically significant results were found across all of the performance measures.

Non-significant results were only found in Experiment 2 for near transfer items. Although there was no statistical significance, on average Group 3 still outperformed Group 1. Effect sizes are demonstrated below in table 7.1.

<table>
<thead>
<tr>
<th></th>
<th>Recall</th>
<th>Near Transfer</th>
<th>Far Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>0.139</td>
<td>0.398</td>
<td>0.277</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>0.328</td>
<td>0.278</td>
<td>0.473</td>
</tr>
<tr>
<td>Experiment 3.1</td>
<td>0.374</td>
<td>0.386</td>
<td>0.682</td>
</tr>
<tr>
<td>Experiment 3.2</td>
<td>0.315</td>
<td>0.407</td>
<td>0.501</td>
</tr>
</tbody>
</table>

*Table 7.1 Effect size comparisons for performance measures in each experiment*

In sum, across all three experiments the split-attention effect was confirmed as Group 3 (integrated) consistently outperformed Group 1 (non-integrated) at a statistically significant level on eight of the nine performance measures.

Ginns (2006) meta-analysis of the split attention effect revealed that reducing split attention can lead to substantial learning gains. This thesis adds to the support of his meta-analysis, which studied 50 independent studies yielding performance-based data.

2. Evidence for self-management as non-redundant pieces of information
This finding is unique for the field of CLT and compares non-integrated (conventional split attention) versus non-integrated with guidance (conventional split attention + guidance) across the three experiments. It compared Group 1 versus Group 2.

Experiment 1 found minimal difference between groups 1 and 2 across all three performance measures. The guidance provided to Group 2 was revised after Experiment 1 in an effort to encourage Group 2 to better utilise the assistance offered to them. The results of Experiments 2 and 3 differed dramatically from those of Experiment 1. For recall items there appeared to be a slightly better average score for Group 2, but not statistically different. For near and far transfer items, Group 2 outperformed group 1 at a statistically significant level for both experiments. Effect sizes are documented in Table 7.1.

3. The impact of self-management within a defined learning area when compared to instructor manipulated load

This finding relates to the comparison of Group 2 and Group 3; Conventional split attention + guidance versus integrated.

For Experiment 1, the integrated group outperformed Group 2 across all performance measures at a statistically significant level. For Experiment 2, the integrated format was significantly better than Group 2 across recall and far transfer performance items. For near transfer items, it was found that Group 2 slightly outperformed Group 3 but not at a statistically significant level. Effect sizes are documented in Table 7.1.
For Experiment 3 the integrated group outperformed Group 2 for recall and far transfer. There were no significant differences between groups 2 and 3 for near transfer items.

4. The impact of self-management in a new learning domain

The unique results of this thesis occurred with Part 2 of Experiment 3 was conducted. This was a test that sought to investigate whether, if participants were given a new set of materials, any skills regarding split attention management would transfer to a novel domain. Group 2 outperformed both Group 1 and Group 3 for recall and near transfer items. For far transfer items there were no differences between groups, but this was possibly due to ceiling effects and the nature of the question itself.

The results from this thesis study show promise and potential for future CLT studies to investigate how students can self-manage cognitive load when exposed to inefficiently designed learning materials. The results from Experiment 3, Part 2 are particularly promising, as these show generic self-management skills may be transferred to new contexts.

In summary, the main issues that have been confirmed by the research in this thesis are:

- It is possible to instruct students on how to self manage cognitive load to benefit their learning
- Efforts to self-manage split attention should be made prior to attempts at learning the material
• Relevant information must be placed in close proximity to a diagram in an effort to reduce the need for ‘search and match’ processes, which exhausts limited working memory capacity

• Highlighting, numbering and placing arrows that relate important information to its corresponding place in the diagram facilitates learning

• Generic self-management skills can be transferred to new tasks.

7.3 Theoretical and methodological considerations – Implications from CLT

As discussed, CLT has focussed largely on instructor-manipulated load. This thesis expands on work within CLT that is trying to focus more on the learner having some level of control in relation to cognitive load. Slava Kalyuga (2006) (Kalyuga & Sweller, 2005) and his rapid dynamic assessment model is an example of research that is trying to expand in the area. Kalyuga (2007a) and rapid dynamic assessment place the learner at a level commensurate with their abilities (via a simple screening test) so mundane tasks are avoided if the student is at a level beyond basic understanding. By assessing the learners’ ability, they are placed at the level required to extend their knowledge in an area. For those needing a more graded approach, they might need to start at a more basic level before working their way to more complex examples. Rapid dynamic assessment illustrates the benefit of adapting the learning environment to better suit learners. Despite these innovations the onus is still on the instructor to ultimately manage the load. This thesis is the first movement away from instructor-manipulated load, where learners are being equipped with the skills to self-manage. There have been slight changes to the instructional environment (i.e., provision of guidance) but this is generic in nature and can be easily transferred to other contexts.
The implications of this thesis are numerous and promising. Self-management of cognitive load is a unique direction for cognitive load. It extends the field of CLT by generating a new direction of investigation may warrant attention for all cognitive load effects, not just split attention.

Extraneous load hampers learning efforts and, if students can be directed on how to reduce extraneous load by identifying cognitive overload, this can only mean more efficient learning opportunities in the future. Despite concerns that Group 2 (split attention management) were asked to perform additional tasks, this did not appear to impede their learning efforts when the tasks were performed as a preliminary to learning.

Compliance measures provided useful insight into how students were using the guidance. Without such measures it would be difficult to gauge whether students had, in fact, used the guidance, especially when many participants report they did not find the guidance particularly useful. Future studies should consider compliance measures as a useful methodological tool.

This study failed to produce any useful mental effort ratings that would serve to complement performance measures (and thus give efficiency measures). This issue needs to be more closely investigated; careful use of the original scale developed by Paas (1992) may have provided more useful data. Reasoning for the results may be due to the nature of the likert scales used for all three experiments in this thesis, as the nine-point scales only labelled 5 of the 9 possible numbers that a participant could allocate a rating.
(see Figure 4.3). As a result, many of the participants rated their mental effort in the middle range, which did not provide much variance across scores. The labelling of the likert scales may also be reconsidered as participants were unsure as to what ‘mental effort’ constitutes. Australians tend to have a different conceptualisation of mental effort when compared to the European participants where the scale has been developed and validated.

7.4 Limitations of the current thesis

The main challenge within this thesis was the measurement of cognitive load. The issue has been widely discussed in the literature and is a challenge that needs to be addressed by the CLT field (Sweller, 2010; Sweller et al., 2011; van Gog & Paas, 2008). It is not limited to this thesis. An appropriate scale that can measure the amount of mental effort a participant contributes to the learning exercise needs to be produced. Validation with Australian university students would be beneficial to future studies investigating aspects of cognitive load.

Mental effort ratings were collected for each experiment. Ratings were provided by participants at the end of the learning phase and at completion of recall items, near transfer items and far transfer items (see appendices section for detail). Unlike many of the previous studies, that were able to equate efficiency rating that coincided with the perceived difficulty of test items, this research was unable to produce any significant finding for mental effort ratings. No inferences regarding load were able to be made. This
may relate to slight variations in the original Paas (1992) scale (this thesis did not include all labels to assigned ratings of 1-9).

Another limitation of the study was an additional difference between the group taught to self-manage split-attention and the other groups, which is that the instructions to the split attention group asked them to emphasise keywords in their approach to the material. On the face of it, it is possible that this difference in instruction contributed to the difference in performance between the groups. However, in the response to the qualitative question asked at the end of each experiment, where participants were invited to comment on the methods they used, it was clear that equivalent numbers of participants in all three groups used a strategy of highlighting keywords. In Experiment 1, 44% of participants in Groups 1 and 2 and 34% of group 3 reported highlighting keywords. For Experiment 2, 21% of participants in Group 1 indicated they highlighted keywords, Group 2 included 29% and 34% for those allocated to Group 3. This suggests that although the groups were instructed differently in this regard it did not result in a genuine difference in behaviour that might have contributed to differences in performance. However, future research should ensure that the instructions are equivalent across the experimental conditions.

Another aspect of the research that may have affected results was the transfer questions for the second part of the third experiment. The results suggest that the far transfer question was not difficult enough to differentiate groups. Future replication of the study needs to refine these items, highlighting the importance of carefully planning transfer questions to ensure the best test of the experimental design.
7.5 Ideas for Future Research and Practical Implications

Future research into the area of self-directed learning and cognitive load management could examine the other instructional effects within CLT. This thesis focussed exclusively on split attention and self-management of cognitive load. There are many effects that also could be investigated (e.g., redundancy, worked example, expertise-reversal). Experimental studies investigating efficient methods of guiding students to manage their cognitive load will further improve the tools provided to students during their future studies.

Another area where self-management of cognitive load should be investigated is multimedia learning. The studies in this thesis used paper-based materials however, the bulk of current student learning occurs electronically. Following from the research presented in this thesis Agostinho, Tindall-Ford and Roodenrys (2011) attempted to investigate self-management of cognitive load to electronic media. The research used electronic whiteboard technology through use of the EndNote program to examine self-management of split attention.

The findings of the current research in this thesis have a number of implications for the instructional design of learning materials. There are implications for general study skills courses provided to university students. The implications are vast for online learning environments. Recent interest in CLT research has surfaced from the field of air traffic control research. Examining tools that might assist traffic controllers to reduce extraneous load has generated interest from researchers wishing to improve the tools that potentially
assist workers manage a cognitively demanding job with competing demands that require immediate attention. Neal, Flach, Mooij, Lehmann, Stankovic & Hasenbosch (2011) and Loft, Sanderson, Neal, Mooij (2007) refer to the need for air traffic controllers to manage cognitive resources and self-regulate their performance. Dr Andrew Neale of the University of Queensland is currently examining ways to integrate CLT into the air traffic control system, in an effort to improve the tools available for workers self-manage cognitive load.

7.5.1 “How to study” courses within schools and universities

The majority of universities provide learning and development services that are accessible to staff and students. These units offer information and courses that assist navigating the university environment to optimise learning opportunities. For example, students can attend short courses that provide advice regarding note taking during lectures, referencing, studying for exams, critical thinking, academic writing, report writing and writing a thesis. Often this information is made available to students via links within university websites. Such programs employ metacognitive strategies and general cognitive strategies, as a result of extensive research surrounding memory structures, strategy instruction and human learning in general. The primary goal of such services is to offer students support in their university studies (Bruning et al., 2004). The lack of randomised controlled experiments examining the benefits of these courses is somewhat lacking though.

Thus, generic skills training in CLT principles should be provided to students who access services that are meant to support and enhance their learning efforts. If such services can
provide students with worked examples of how to best manage and identify split attention (amongst other CLT effects), this is a practical skill that can be taught to students at university.

7.5.2 “How to study” tips in textbooks

Textbooks today have many additional features at the beginning of the book or at the beginning and end of each chapter. This thesis has identified potentially useful tips on how to self manage split attention. Again, worked examples of split attention and basic tips on how to best manage split attention might be useful within a section at the beginning or end of a textbook. Other cognitive load effects have developed advice for instructional designers that could be relayed to students. Further research into other effects could emphasise study tips for all instances of cognitive load.

7.5.3 “How to study” tips applied in computer applications

With the wealth of online resources it is important that students identify ineffective materials and have the skills to modify them to help them in their study. Further work is being conducted in this area by Agostinho et al. (2011) to investigate if self-management of cognitive load can translate to online resources. This thesis focussed on paper-based manipulation of resources. Future directions include the development of resources that enable students to effectively limit split attention for computer-based information.

7.6 Conclusion

Can we teach students to manage their own cognitive load? The results from this thesis highlight that this is possible. This series of experiments shows definite potential for
students to manage their load if given the correct guidance that aligns with the rules governed by cognitive load theory in relation to the restraints of human memory. It is a unique and exciting direction for cognitive load theory research. Future directions include investigating the many cognitive effects established by cognitive load theory research. These efforts can only hope to refine potential guidance that students may be offered to benefit their own future learning.

In sum, four key themes were generated by this thesis:

1. The robustness of the split-attention effect
2. Evidence for self-management as non-redundant pieces of information
3. The impact of self-management within a defined learning area when compared to instructor manipulated load
4. The impact of self-management in a new learning domain

All four key findings indicate the need to further investigate the possibility of a ‘self-management effect’. Computer based research may provide impetus for the development of the effect. Examining other effects may also provide support for the emerging effect. This thesis indicates that the development of the effect is at its foundation stages. Further research might prove to be a useful future direction for cognitive load research. For the ‘self-management effect’ to be established requires extensive practice within new learning domains.

In summary, it is important that cognitive load research principles are disseminated so that they are placed in the hands of the learner. By empowering learners to recognise
poorly designed materials they can revise the information provided to enable more efficient student centred learning.
References


References emerging from this research:


Managing one’s own cognitive load when evidence of split attention is present

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Abstract

There is an increasing expectation in tertiary education that students take control of their own learning, experience independence and manage their own cognition. This research sought to investigate techniques for university students to manage their own cognitive load. This paper presents two experiments conducted with postgraduate university students enrolled in an educational psychology subject in an Australian university. A total of 86 students participated in Experiment 1 and 85 in Experiment 2. The results of both experiments show that it is possible to instruct students on how to self-manage split attention. Furthermore, the findings from Experiment 2 show that students can transfer skills of split-attention management when provided with new instructional materials. The implications for this unique direction of cognitive load theory research are discussed.

Keywords: cognitive load theory, split-attention effect, extraneous cognitive load, self-directed learning
Introduction

Cognitive Load Theory (CLT) has identified a number of design principles that inform the development of instructional materials to support the efficient use of working memory. The focus of research in CLT over the last three decades has been on how instructional designers or educators can optimally design learning materials based on CLT principles (instructor-managed cognitive load). One well known design principle is integrating spatially separated sources of information such as text and diagram to reduce the need for a learner to search and match the relevant information (split-attention effect). The study reported in this paper examined how learners can self-manage cognitive load when presented with instructional materials with evident split attention. This study represents a new area in CLT research, as this is one of the first studies that has focused on empowering learners to manage their own cognitive load by being taught CLT design principles that they can apply when studying instructional materials not designed based on CLT techniques (self-managed cognitive load).

Cognitive load theory (CLT) (see Sweller, Ayres, & Kalyuga, 2011, for a review) is premised on human cognitive architecture that assumes a working memory with limited capacity, and an unlimited long-term memory in which information is stored in the form of schemas. From this theoretical framework, a variety of strategies have been developed to reduce the load placed on a learner’s working memory to provide better learning opportunities. Principles to emerge from the research, named after the manipulations that demonstrate them, include: worked example effect (Sweller & Chandler, 1994), split attention effect (Tarmizi & Sweller, 1988), redundancy effect
(Chandler & Sweller, 1991), expertise reversal effect (Kalyuga, Ayres, & Sweller, 2003) and the imagination effect (Leahy & Sweller, 2004).

The split-attention effect is an attentional phenomenon that has a direct effect upon the comprehension of information. Research on the split-attention effect has demonstrated that split-attention instructions are very difficult to understand and consequently have negative outcomes for learning (Ginns, 2006). For example, to understand the information in Figure 1, one needs to mentally integrate the diagram and accompanying text, as neither is intelligible in isolation. To understand this material, the learner must hold small segments of text in working memory while searching for the matching diagrammatic entity, with this ongoing process continuing until all the information is rendered intelligible. Because there is less need to search and match with integrated materials, extraneous cognitive load is significantly reduced, making it easier to learn (Sweller, Paas, & van Merrienboer, 1998).

Figure 1 goes here

The focus of CLT research over the last two decades has been on developing alternative instructional formats that physically locate related information and joins them together in order to avoid extensive searching and matching and thus reducing extraneous load. An example of an integrated instructional design is demonstrated in Figure 2. Fragments of text are directly embedded into the diagram in close proximity to corresponding components of the diagram. Arrows directed from the text to the
corresponding elements of the diagram were used to make the search process easier for learners.

Figure 2 goes here

The foundation research into split-attention was conducted by Tarmizi and Sweller (1988) who utilised geometry problems with worked examples. Tarmizi and Sweller (1988) were concerned that previous attempts to use worked examples in the mathematical domain were highly effective but for geometry it was not the case. Further investigation lead Tarmizi and Sweller (1988) to conclude that the separation of diagram and the necessary solution path was placing additional strain on working memory. This research demonstrated, by integrating the information contained in the worked examples (diagram and solution), that participants given the integrated information outperformed those who were presented with the original format (which required them to split their attention). Following the Tarmizi and Sweller (1988) work, a number of key studies explored the split-attention effect in the content domains of mathematics (Sweller, Chandler, Tierney & Cooper, 1990), physics (Ward & Sweller, 1990), electrical engineering (Chandler & Kalyuga, 1991), instruction of computer software (Kalyuga, Chandler, & Sweller, 1999), instructional multimedia (Mayer & Chandler, 2001; Moreno & Mayer, 1999), and more recently, music instruction (Owens & Sweller, 2008).

CLT research focused on split-attention has consistently indicated the reduction of extraneous load occurs when learning materials are integrated to assist more efficient processing. Currently, the most efficient method for dealing with split-attention is
thought to be through integrated instructions. This technique, which requires instructor-manipulated interventions, represents a form of *instructor-managed cognitive load*.

The two experiments reported in this paper represent a different direction for the use of CLT in education. Previous research has focussed on the use of CLT in designing instructional material for educators, but there is no research that has investigated student application of CLT design principles. Thus, this series of experiments examined the effects of teaching students strategies to manage their own cognitive load. The split-attention effect was chosen as it is the most common effect demonstrated in instructional materials across all educational domains (Clark, Nguyen, & Sweller, 2006).

The overall objective of this study was to examine how learners can self-manage cognitive load when presented with instructional materials with evident split-attention. The central hypothesis was that learners who are guided on how to self-manage cognitive load when presented with instructional materials with evident split-attention outperform learners who are presented with instructional materials with evident split–attention and not given guidance.

For both experiments, participants were randomly assigned to one of three conditions:

4. Conventional split-attention formatted instructional materials (Group 1 - split-attention)

5. Conventional format and given guidance on how to manage split-attention (Group 2 – self-managed cognitive load)
6. Integrated instructional materials (Group 3 – instructor-managed cognitive load)

   The purpose of Experiment 1 was to firstly confirm the split-attention effect in the instructional materials, that is, test that condition 3 (Group 3) was superior to condition 1 (Group 1), and secondly test whether the guidance devised to assist learners to self-manage the split-attention effect (Group 2) led to better learning performance than then conventional split-attention condition (Group 1).

   Experiment 2 used the same instructional materials as Experiment 1 but was extended to include a transfer task that examined if participants (Group 2) could apply their knowledge of self-managing the split-attention effect to a new learning domain. There were two parts to the experiment. Part 1 replicated Experiment 1 and in Part 2, participants in each of the three groups were presented with a set of new instructional materials with evident split-attention and performance was measured similar to Part 1. Pilot studies were conducted prior to each experiment to refine the instructional and test materials.

**Experiment 1**

It was predicted that the integrated condition (Group 3) would outperform the split-attention condition (Group 1) in performance measures due to the reduction in extraneous cognitive load imposed by integrated instructional formats (hypothesis 1). It was also expected that the conventional split-attention plus guidance condition (Group 2) would outperform Group 1 (conventional split-attention) in performance measures because the
guidance about self-managing cognitive load would serve to reduce extraneous load (hypothesis 2).

Method

Participants and Design

A total of 86 university students (61 females, 25 males, aged 21-44) volunteered to participate in the first experiment. The mean age for participants was 26.31 ($SD = 4.78$). All participants were enrolled in a graduate teaching program (2009 cohort) at an Australian university. Participants who indicated prior knowledge of the information being presented were excluded from the study (n=3).

Participants took part in this experiment during the final 25 minutes of tutorial time. Four separate tutorial classes were involved in the study. They had been informed of the study one week prior to it being conducted. All were informed of the general nature of the experiment and what would be required if they agreed to participate.

Materials and Procedure

The instructional material explained Urie Bronfenbrenner’s ‘Ecological systems theory’ was presented in an educational psychology textbook (Vialle, Lysaght, & Verenikina, 2008, pp.172-174) in the form of split attention. Thus, for purposes of this research, the same content about the ‘Ecological systems theory’, which comprised two pages in the textbook, was presented to each group but formatted as follows for each of the three conditions:
**Group 1 – split attention instructional materials:** The content was formatted in a similar way as in the textbook but presented on an A3 sheet of paper so that participants could view all the content from one sheet of paper (see Figure 1).

**Group 3 – integrated instructional materials:** The content was reformatted to reduce split attention by integrating the text with the diagram. Developing the integrated material involved firstly reviewing the research concerning split attention (e.g., Ayres, 2005; Chandler & Sweller, 1991; Tarmizi & Sweller, 1988) and reformatting the content presentation appropriately (see Figure 2).

**Group 2 – split-attention instructional materials with guidance:** Group 2 instructional materials were developed to assist participants to integrate the text with the diagram in a similar to the integrated format. The explicit guidance was presented on a separate A4 piece of paper attached/stapled to the front of the learning materials that were presented on an A3 sheet of paper. Participants were explicitly asked to implement the guidance (see Figure 3) before attempting to learn the materials.

All participants were asked to review their materials for 10 minutes (learning phase). Following the learning phase, the researcher handed out to all participants a post-test that was formatted as single sided stapled A4 booklet. The test consisted of recall, near transfer and far transfer items. Participants were given 15 minutes to complete the post-test.

The recall item required participants to record all relevant aspects of the diagram (each component of ecological systems theory-see Figure 1) and had a maximum score of
15. Examples of near transfer were: “What system impacts on the child due to changes in their environment over time?” and participants could achieve a maximum score of 3. Far transfer items included: “A homework centre in the local community has closed down due to lack of funding. What system does this correspond to?” and participants could achieve a maximum score of 4. All post-test measures were considered dependant variables (recall, near transfer, far transfer).

Compliance was an additional measure included for analysis. ‘Compliance’ was measured for participants allocated to Group 2 of the experiment. Compliance referred to participant use of the guidance attached to the instructional materials. Participants in Group 2 were considered ‘compliant’ if they utilised at least one of the three strategies provided in the guidance. Evidence of compliance required examination of the instructional materials (A3 sheet of paper) to determine if participants had implemented the guidance.

Mental effort ratings were asked from participants at the completion of the learning phase, for example, “How much mental effort did you invest to learn this material?” and after each question in the post-test, for example, “How much mental effort did you invest to answer this question?” Mental effort ratings are considered a subjective measure of cognitive load that have been developed and tested during the past 20 years of CLT research (Paas, 1992). The rating provides an indication of the mental effort involved in a task. Subjective measures have been demonstrated to be as effective in assessing mental load as physiological measures such as pupil dilation and heart beat patterns (Paas, Tuovinen, Tabbers, & Van Gerven, 2003; van Gog & Paas, 2008).
mental effort rating scale as developed by Paas (1992) was used except due to text formatting constraints only 1, 3, 5, 7, 9 were labelled. Rating 1 indicated ‘very, very low mental effort’, 3 indicated ‘low mental effort’, 5 indicated ‘moderate mental effort’, 7 was ‘high mental effort’ and 9 ‘very, very high mental effort’.

At the completion of the testing session participants were given the opportunity to describe the techniques they used in conducting the learning task. Although qualitative analysis of these responses has been conducted, this data has not been extensively reported here due to length restrictions.

**Results and Discussion**

One-way analysis of variance (ANOVA) was conducted on test performance scores to explore any difference between the 3 groups involved in Experiment 1. Means and standard deviations are included in Table 1. An alpha level of 0.05 was used as the criterion for determining statistical significance.

Table 1 goes here

**Performance Measures**

A one-way ANOVA indicated a significant main effect of group for the recall test items, $F(2, 83) = 4.91, MSe = 9.266, p < .05$, effect size (partial $\eta^2$) 0.33. Post-hoc comparisons using Bonferroni contrasts showed Group 3 performed significantly better on recall than Groups 1 and 2. There was no significant difference between Group 1 and Group 2, despite a slightly higher mean for the group with guidance (Group 2).
The one-way ANOVA for near transfer questions also demonstrated a significant main effect of group, $F(2, 83) = 3.384, MSe = .615, p < .05$. Effect size 0.28. Post-hoc comparisons using Bonferroni contrasts indicated Group 2 performed slightly, but not significantly, better than Group 3, however Group 2 performed significantly better than Group 1.

One-way ANOVA for the far transfer test items also revealed a significant main effect of group, $F(2, 84) = 11.640, MSe = 1.477, p < .05$. Effect size 0.47. Results indicated Group 3 outperformed Groups 1 and 2. Again Group 2 outperformed Group 1 at a statistically significant level.

*Mental effort rating on instruction*

A one-way ANOVA was conducted on the instructional rating (of mental effort) that participants were asked to provide directly after the learning phase. Results indicated no significant effect between groups $F(2, 83) = 0.28$. Thus, there was no significant difference between groups for mental load ratings.

*Guidance compliance*

For measures of compliance within Group 2, 89% of participants (24/27) utilised the split attention guidance. Compliance ratings were recorded if participants utilised at least one of the three split-attention management tasks (as seen in Figure 3). The majority of compliant participants performed all 3 suggested tasks (number, link and highlight keywords).
The results from Experiment 1 confirmed both hypotheses in relation to split attention. The split attention effect was replicated with Group 3 outperforming group 1. The second hypothesis was also confirmed which indicated the provision of guidance (Group 2) in managing split-attention can allow participants to learn the material more efficiently. The additional guidance offered to the conventional instructions appears to have improved learning efforts for participants allocated to Group 2.

Experiment 2

Experiment 2 sought to measure the transferability of the split-attention management skills. The results from Experiment 1 showed that providing guidance on how to self-manage split-attention instructional materials was beneficial as the conventional split-attention plus guidance condition (Group 2) outperformed the conventional split-attention condition (Group 1) on transfer items. Experiment 2 sought to explore whether this skill might be transferred to a new learning domain. Providing participants with a new set of materials with evident split-attention would test whether they would be able to transfer the skill to a new learning domain thus providing evidence for the self-managed cognitive load effect.

Experiment 2 was structured into two parts. The aim of Part 1 was to replicate the split-attention effect (as evident in Experiment 1) and the aim of Part 2 was to test whether the self-management skills acquired by Group 2 would be transferable to a new learning domain.
Part 1 of Experiment 2 had similar hypotheses as Experiment 1, that is, it was predicted that the integrated condition (Group 3) would outperform split-attention condition (Group 1) in performance measures due to the reduction in extraneous cognitive load imposed by integrated instructional formats (hypothesis 1). It was also expected that the conventional split-attention plus guidance condition (Group 2) would outperform Group 1 (conventional split-attention) in performance measures because the guidance about self-managing cognitive load would serve to reduce extraneous load (hypothesis 2).

For Part 2 of Experiment 2, it was hypothesised that participants allocated to Group 2 in Part 1 of Experiment 2 would transfer self-management skills to the new split-attention instructional materials leading to a reduction in extraneous load and thus outperform Group 1 (hypothesis 2). If the skills were transferred, it was hypothesised that these skills would enhance their performance on post-test measures.

**Method**

**Participants and Design**

In total 85 university students (61 females, 24 males, aged 20-56) volunteered to participate in Experiment 2. The mean age for participants was 26.64 ($SD = 7.33$). All participants were enrolled in graduate teaching program (2010 cohort) at the same Australian university as in Experiment 1. Participants who indicated prior knowledge of the information being presented were excluded from the study (n=4).
Materials and Procedure

Participants who volunteered for the study were exposed to the experiment at the commencement of the four tutorial classes. They had been informed of the study one week prior to it being conducted. All were informed of the general nature of the experiment and what would be required if they agreed to participate. Participants were randomly assigned to one of the three experimental groups.

For Experiment 2, Part 1, the instructional materials were identical to Experiment 1. All participants were given the learning materials on an A3 sheet of paper and asked to study the information for 10 minutes. Participants were informed they would be examined on the content of the document directly after the 10 minute learning phase.

Participants answered the same items used in the testing phase of Experiment 1 – a series of questions measuring recall, near transfer and far transfer. This occurred directly after the learning phase. All performance-based questions were identical to the items used in Experiment 1, including the measure of compliance. Compliance included evidence documented on test materials that participants had adhered to the instructions regarding the use of split attention management guidance. The same mental effort rating scale as in Experiment 1 was used.

Part 2 of Experiment 2 proceeded directly after Part 1. All participants in each of the three conditions were presented with a completely new set of instructional materials that demonstrated evidence of split attention (see Figure 4). Again participants were asked to study the material for 10 minutes, and then to answer questions that related to the content.
Results and Discussion: Experiment 2, Part 1

One-way analysis of variance (ANOVA) was conducted on test performance scores to explore any difference between the 3 groups involved in Experiment 2, Part 1. Means and standard deviations are included in Table 2.

Table 1 goes here

Performance Measures, Part 1

One-way ANOVA indicated a significant main effect of group for recall test items, $F(2,81) = 6.37, MSe = 13.10, p < .05$. Effect size 0.37. Post-hoc comparisons indicated that Group 3 recalled significantly more items than Groups 1 and 2, which did not differ from each other.

The one-way ANOVA for near transfer questions also demonstrated a significant main effect, $F(2,81) = 3.38, MSe = .62, p < .05$. Effect size 0.38. Post-hoc comparisons using Bonferroni contrasts indicated Group 1 performed significantly more poorly than Group 2 or Group 3, which did not differ from each other.

One-way ANOVA for the far transfer test items also revealed a significant main effect, $F(2,81) = 11.64, MSe = 1.48, p < .05$. Effect size 0.68. Results indicated Group 3 outperformed Groups 1 and 2. Again Group 2 outperformed Group 1 at a statistically significant level.

The results for recall, near transfer and far transfer for Part 1 of Experiment 2 was almost identical to the results in Experiment 1. This was expected as it was a repeat of
Experiment 1, with a similar number of participants used for the study. Again compliance measures were recorded to ensure participants implemented the guidance provided.

*Mental effort rating on instruction, Part 1*

A one-way ANOVA was conducted on the instructional rating (of mental effort) that participants were asked to provide directly after the learning phase. Results indicated no significant effect between groups $F(2, 81) = 1.23$. Thus, like Experiment 1, there was no significant difference between groups for mental load ratings $p = .298$.

*Efficiency Ratings, Part 1*

A one-way ANOVA was conducted on the efficiency ratings for recall, near transfer and far transfer. Again, results indicated no significant difference between groups $F(2, 81) = 1.71$. Thus, mental load ratings did not yield significant differences $p = .57$.

*Guidance compliance, Part 1*

For measures of compliance within Group 2, 89% of participants (25/28) utilised the split-attention management guidance. As with Experiment 1, compliance was measured by evidence of using the suggested guidance regarding management of split attention. Compliant ratings were recorded if participants utilised at least one of the two split attention management tasks. The majority of compliant participants (18/25) performed all 3 suggested tasks (number, link and highlight keywords).

The results from Experiment 2, Part 1 confirmed both hypotheses in relation to split attention. The split attention effect was again replicated with Group 3 outperforming conventional groups in performance-based tasks. The second hypothesis was confirmed
which indicated the provision of guidance in managing split-attention can help participants to learn instructional material more efficiently.

The additional guidance offered to the conventional instructions improved performance across all 3 measures. For recall the difference was not statistically significant but for both near and far transfer items Group 2 outperformed Group 1. This leads to the conclusion that the additional instructions provided to Group 2 in the form of guidance allowed learners to actively self-manage extraneous load by conducting the three tasks considered ‘preliminaries to learning’ before attempting to study the experimental materials.

**Results and Discussion: Experiment 2, Part 2**

One-way analysis of variance (ANOVA) was conducted on test performance scores to explore any difference between the 3 groups involved in Experiment 2, Part 2. Means and standard deviations are included in Table 3.

Table 3 goes here

*Performance Measures, Part 2*

One-way ANOVA indicated a significant main effect for recall test items, $F(2, 81) = 4.29, MSe = 3.510, p < .05$. Effect size 0.32. *Post-hoc* comparisons using Bonferroni contrasts indicated that Group 2 recalled more items than Groups 1 and 3.
The one-way ANOVA for near transfer questions also demonstrated a significant main effect, \( F(2, 81) = 7.76, MSe = 1.901, p < .05 \). Effect size 0.41. Post-hoc comparisons using Bonferroni contrasts indicated Group 2 outperformed both Group 1 and Group 3.

One-way ANOVA for the far transfer test items again revealed a significant main effect, \( F(2, 81) = 13.04, MSe = 1.54, p < .05 \). Effect size 0.50. Results indicated Group 3 and Group 2 outperformed Group 1.

Similar to Experiment 1, when students had completed all items they folded their answer booklet inside the test materials and waited for all to complete.

*Mental effort rating on instruction, Part 2*

A one-way ANOVA was conducted on the instructional rating (of mental effort) that participants were asked to provide directly after the learning phase. Results indicated no significant effect between groups \( F(2, 81) = 1.23 \). Thus, like in Experiment 1, there were no significant differences between groups for mental load ratings.

*Guidance compliance, Part 2*

An examination of the experimental materials for those allocated to Group 2 occurred. The results indicated a number of participants repeated the instructions given \( (n= 13) \) in Part 1 of the experiment. The most common response was underlining key words \( (n=10) \), with only a few numbering \( (n=5) \) and 2 linked the text with diagram (drew lines connecting information in the diagram with its corresponding place in text).
The results for Part 2 of Experiment 2 did demonstrate that those allocated to Group 2 were at an advantage to Groups 1 and 3 because they were exposed to self-management of split attention techniques. This in turn provided an ability to reduce extraneous load imposed by the need to search and match between text and diagram to make sense of the materials. Although participants in Group 2 did not self-report the techniques as useful, the performance measures indicated otherwise.

**Discussion**

The major finding from this study relates to the ability of students to learn to manage the cognitive load created by instructional materials that require them to split their attention between text and diagrams. As a precursor to this it was essential to demonstrate that the materials do indeed create such a burden, and that it impacts on learning. Both experiments showed that when split-attention was managed for participants by presenting the text and diagram in an integrated format (cf. Chandler & Sweller, 1991), they consistently outperformed those allocated to non-integrated materials, thus replicating the split-attention effect with these materials. It is important to note that the benefit of providing integrated material was apparent even if the other participants were instructed to integrate the materials for themselves.

For Experiment 1, participants in the integrated condition performed significantly better than the self-management group across recall and far transfer performance items. For near transfer items, it was found that the self-management group slightly outperformed the integrated group but not at a statistically significant level. Effect sizes are documented in Table 4. For Experiment 2, the integrated condition outperformed the self-management group for recall and far transfer. There were no significant differences
between the self-management and integrated groups for near transfer items. Given the additional load on the self-managing group, due to the requirement to perform the integration of material, the lack of improved performance in this group is perhaps not surprising. In effect, the instructions to this group require them to split their efforts between learning the material and changing the format.

The most interesting outcome from this study is the evidence supporting the suggestion that teaching participants how to self-manage the split-attention effect will benefit learning. The aim of the study was to investigate if such instruction could provide participants with a new strategy to manage split attention and aid in their learning of novel material. When faced with the task of learning a new set of materials, the self-management group outperformed the convention split-attention format and the integrated format groups for recall and near transfer items, suggesting that they have learned a new strategy that effectively improves learning. For far transfer items there were no differences between the self-management group and the integrated format group, however both groups performed better than the traditional format group. But, performance was quite high on this task raising the concern of ceiling effects obscuring the pattern of results, and it may be that the test questions were not entirely appropriate.

The results from the research show promise and potential for future cognitive load theory studies to investigate how students can self-manage cognitive load when exposed to inefficiently designed learning materials. The results from Experiment 2, Part 2 are particularly promising as it shows generic skills can be transferred to new contexts.

The main limitation of the research was measurement of cognitive load. This study failed to produce any useful mental effort ratings that would serve to compliment
performance measures (and thus give efficiency measures). This issue needs to be more closely investigated and careful use of the original scale developed by Paas (1992) may have provided more useful data.

Another limitation of the study was an additional difference between the group taught to self-manage split-attention and the other groups, which is that the instructions to the split attention group asked them to emphasise keywords in their approach to the material. On the face of it, it is possible that this difference in instruction contributed to the difference in performance between the groups. However, in the response to the qualitative question asked at the end of each experiment, where participants were invited to comment on the methods they used, it was clear that equivalent numbers of participants in all three groups used a strategy of highlighting keywords. In Experiment 1 44% of participants in Groups 1 and 2 and 34% of group 3 reported highlighting keywords. For Experiment 2, 21% of participants in Group 1 indicated they highlighted keywords, Group 2 included 29% and 34% for those allocated to group 3. This suggests that although the groups were instructed differently in this regard it did not result in a genuine difference in behaviour that might have contributed to differences in performance. However, future research should ensure that the instructions are equivalent across the experimental conditions.

The findings of this research have a number of implications for the instructional design of learning materials. There are implications for general study skills courses provided to university students. Worked examples of split attention and basic tips on how to best manage split attention might be useful within a section at the beginning or end of a textbook. Other cognitive load effects have developed advice for instructional designers
that could be relayed to students. Further research into other effects could emphasise study tips for all instances of cognitive overload.

Other areas where self-management of cognitive load should be investigated is multimedia learning. Agostinho, Tindall-Ford and Roodenrys (2011) attempted to investigate self-management of cognitive load to electronic media. The research used interactive whiteboard software that allowed movement of text objects on a screen whereby text can be positioned more closely to a diagram. This research is ongoing and currently being revised to run another experiment.

Future research into the area of self-directed learning and cognitive load management needs to look at the other instructional effects within cognitive load theory. Experimental studies investigating efficient methods of guiding students to manage their cognitive load will further improve the tools provided to students during their studies. Replication of studies investigating a potential ‘self-management effect’ is also a future direction.

**Conclusion**

In summary, the results of the two experiments reported in this paper have demonstrated that it is possible to instruct students on how to self manage cognitive load to benefit their learning. The procedure followed suggests that efforts to manage split attention by restructuring the material, using highlighting, arrows and placing material in proximity with diagrams, applied prior to learning the material, results in as effective learning as if the work of integration had been done for the student. Further research is required to
specify the key factors involved in self-management of cognitive load and to develop efficient ways of teaching students how to self-manage cognitive load.
References


Ecological Systems Theory (by Urie Bronfenbrenner)

This child is viewed as developing within a complex system of relationships that are shaped by influences at many levels within the surrounding environment. The theory focuses on the context of the environment in which children develop, rather than on development itself. The environment is regarded as a series of structures (diamant) that are embedded in one another. From this perspective each figure in the child's environment is seen as exerting powerful influences on development. Figure 1 below illustrates the layers of the theory.

Figure 1: Example of split-attention materials
The 3 tasks below will help you to learn the material more effectively by making efficient use of your working memory.

Please complete the tasks **before** you start reading the material presented on the A3 page:

4. Draw a circle around the information for each system on the right hand of your page (microsystem, mesosystem, exosystem, macrosystem, chronosystem). NOW draw an arrow to link it to it’s corresponding place in the diagram. The first one has been done for you.

5. **NUMBER** each system in sequence (eg., 1. Microsystem, 2. Exosystem, 3. Mesosystem etc) on the diagram and the text. The first one has been done for you.

6. **Now read through the material.** Whilst learning the material, emphasise (circle, underline, highlight) key words on your paper (with a pen/highlighter).
Figure 4: Part 2, Experiment 2 Learning material

Table 1: Experiment 1 - Means and Standard Deviations (in parentheses) for Test Scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Performance Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recall (Mean, SD)</td>
</tr>
<tr>
<td>1 – Conventional (n=27)</td>
<td>9.34 (3.67)</td>
</tr>
<tr>
<td>2 – Conventional + Guidance (n=27)</td>
<td>10.11 (3.17)</td>
</tr>
<tr>
<td>3 – Integrated (n=29)</td>
<td>11.81 (2.11)</td>
</tr>
<tr>
<td>Total Score</td>
<td>/15</td>
</tr>
</tbody>
</table>
### Table 2: Experiment 2, Part 1 - Means and Standard Deviations (in parentheses) for Test Scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Performance Measures</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Recall</td>
<td>Near Transfer</td>
<td>Far Transfer</td>
<td></td>
</tr>
<tr>
<td>1. Conventional (n=29)</td>
<td>9.052 (4.09)</td>
<td>1.90 (1.05)</td>
<td>1.38 (.86)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Conventional + Guidance (n=28)</td>
<td>10.23 (3.67)</td>
<td>2.57 (.50)</td>
<td>2.64 (1.10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Integrated (n=24)</td>
<td>12.58 (2.87)</td>
<td>2.58 (.72)</td>
<td>3.42 (.72)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Score</td>
<td>/15</td>
<td>/3</td>
<td>/4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Experiment 2, Part 2 - Means and Standard Deviations (in parentheses) for Test Scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Performance Measures</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Recall</td>
<td>Near Transfer</td>
<td>Far Transfer</td>
<td></td>
</tr>
<tr>
<td>1 – Conventional (n=29)</td>
<td>7.21 (2.26)</td>
<td>2.34 (1.59)</td>
<td>1.86 (1.46)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 – Conventional + Guidance (n=28)</td>
<td>8.64 (1.52)</td>
<td>3.75 (1.24)</td>
<td>3.25 (1.32)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 – Integrated (n=24)</td>
<td>8.12 (1.78)</td>
<td>2.75 (1.26)</td>
<td>3.42 (.78)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Score</td>
<td>/10</td>
<td>/4</td>
<td>/4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix A

*Pre-test used for Experiment 1-3*
Please complete the following items:

Age:

Sex: (please tick) Male ☐ Female ☐

Course enrolled in:

Q1. Have you ever encountered Urie Bronfenbrenner’s ‘Ecological Systems Theory’?
   Yes ☐ No ☐

If yes, please explain your knowledge of the theory?

Q2. Please rate your knowledge of Child Development Theory
   (please circle)

1-------------------------2-------------------------3-------------------------4-------------------------5
very little knowledge     little knowledge     fair amount of knowledge     good amount of knowledge     great deal of knowledge

Thank you for participating in this study. If you would like to receive information that relates to this study and may benefit your future learning at university please provide your email address below.

Email Address:
Appendix B

*Instructional Materials for Experiment 1,2,3 (part 1)*

*Group 1*

Note: whilst printed on two sheets of A4 paper in the Appendix, these materials were presented to the students on one A3 sheet of paper
Ecological Systems Theory (by Urie Bronfenbrenner)
The child is viewed as developing within a complex system of relationships that are shaped by influences at many levels within the surrounding environment. The theory focuses on the context or the environment in which children develop, rather than on development itself. The environment is regarded as a series of structures (illustrated as layers) that are embedded in one another. From this perspective each layer in the child’s environment is seen as exerting a powerful influence on development. Figure 1 below illustrates the layers of the theory;

Figure 1 – Ecological Systems Theory
**Microsystem** – Immediate context where the child develops: Home (including parents, siblings) school (including friends, peers) and the local community. This setting is where the majority of research into child development takes place.

**Mesosystem** – connections between the microsystem. For example, the way the family interact with the school will demonstrate the influence that both environments have on academic progress. When learning is valued in the home and effective communication with the school, opportunities for success are likely to be increased.

**Exosystem** – Places the child does not enter very often but has an indirect effect on their development. This includes; parents place of work, community based services, mass media and extended family. For example, children’s lives can be significantly affected by what happens in their parents’ places of employment, even though they may never enter them. Factors such as pay rise, loss of employment or added pressures all influence the relationships and contexts in which children operate. Another example is mass media: television, radio and other aspects of the media affect children constantly and yet they generally have no control or input into their content.

**Macrosystem** – Values, Beliefs, customs and laws shared by the culture. These factors all contribute to the functioning of various systems such as the family, the legal system and the education system.

**Chronosystem** – Changes in the child’s overall environment that occurs across time. These changes may produce changes that significantly impact on a child’s development. Examples include birth of a sibling, moving house, parent divorce.

Bronfenbrenner’s model allows one to develop a more comprehensive picture of child development by taking into account the child, the immediate setting in which interactions occur as well as the variety of other contexts that influence development. It emphasises the dynamic nature of a child’s development through the integration of a complex array of factors.

Appendix C

Instructional Materials for Experiment 1

Group 2

Note: whilst printed on two sheets of A4 paper in the Appendix, these materials were presented to the students on one A3 sheet of paper
As you read through the following information, tips on how to improve your understanding of the information are indicated by the symbol 🌟. Feel free to write on your materials with the pen, pencil and highlighter provided.

Ecological Systems Theory (Urie Bronfenbrenner)
The child is viewed as developing within a complex system of relationships that are shaped by influences at many levels within the surrounding environment. The theory focuses on the context or the environment in which children develop, rather than on development itself. The environment is regarded as a series of structures (illustrated as layers) that are embedded in one another. From this perspective each layer in the child’s environment is seen as exerting a powerful influence on development. Figure 1 below illustrates the layers of the theory;

Figure 1 - Ecological Systems Theory
**Microsystem** – Immediate context where the child develops: Home (including parents, siblings), school (including peers, friends) and the local community. This setting is where the majority of research into child development takes place.

**Mesosystem** – Connections between the microsystem. Eg., the way the family interact with the school will demonstrate the influence that both environments have on academic progress. When learning is valued in the home and effective communication with the school, opportunities for success are likely to be increased.

**Exosystem** – Places the child does not enter very often but has an indirect effect on their development. This includes: parents place of work, community-based services, mass media and extended family. For example, children’s lives can be significantly affected by what happens in their parents’ places of employment, even though they may never enter them. Factors such as pay rise, loss of employment or added pressures all influence the relationships and contexts in which children operate. Another example is mass media: television, radio and other aspects of the media affect children constantly and yet they generally have no control or input into their content.

**Macrosystem** – Values, Beliefs, customs and laws shared by the culture. These factors all contribute to the functioning of various systems such as the family, the legal system and the education system.

**Chronosystem** – The change in the child’s environment over time. These changes may produce changes that significantly impact on a child’s development. Examples include birth of a sibling, moving house, parent divorce.

Bronfenbrenner’s approach allows one to develop a more comprehensive picture of child development by taking into account the child, the immediate setting in which interactions occur as well as the variety of other contexts that influence development. It emphasises the dynamic nature of a child’s development through the integration of a complex array of factors.

Appendix D

Instructional Materials for Experiment 1,2,3 (Part 1)

Group 3
Note: The material for group 3 was presented to the students on one A3 sheet of paper
Ecological System Theory by Urie Bronfenbrenner

The child is viewed as developing within a complex system of relationships that are shaped by influences at many levels within the surrounding environment. The theory focuses on the context as the environment in which children develop, rather than on development itself. The environment is regarded as a series of structures (illustrated as layers) that are embedded in one another. From this perspective each layer in the child’s environment is seen as exerting a powerful influence on development. The diagram below illustrates the layers of the theory:

1. The microsystem – Immediate context where the child develops. This includes parents, siblings, school (including formal, peer) and the local community. This setting is the most direct context for human interactions and development.

2. Mesosystem – Connections between the microsystem. For example, the ways a family interacts with the school will determine the level of support that is provided. Programs seek to increase the level and quality of support and encouragement with the family, thus improving the chances for success.

3. Exosystem – The child does not always have a direct effect on their development. This includes parents’ place of work, community-based services, mass-media and extended family. For example, children’s lives can be significantly affected by what happens within their parents’ workplace although they may not know about these events, such as pay cuts, loss of employment or reduced services that influence the relationship and functioning of children.

4. Macrosystem – Values, beliefs, customs and laws shared by the culture. These factors all contribute to the formation and development of various systems such as the family, legal system and the education system.

5. Chronosystem – Changes in the child’s overall environment that occur over time. These changes may produce changes that significantly impact on a child’s development. Examples include birth of a sibling, moving house, parental divorce.

Bronfenbrenner’s model allows one to develop a more comprehensive picture of child development by taking into account the child, the immediate settings in which interactions occur as well as the variety of other contexts that influence development. It emphasizes the dynamic nature of a child’s development through the integration of a complex array of factors.

Adapted from Valli, Lyonette & Vennila, 2004, p. 127-129.
Appendix E

Post-test items for Experiment 1
**Question 1.** How much mental effort did you invest to learn this material? (please circle)

1---------2--------3-------4-------5-------6-------7-------8-------9

very, very low mental effort low mental effort moderate mental effort high mental effort very, very high mental effort

Please turn over for more questions
**Question 2.** Please complete the diagram below to provide a representation of the Ecological Systems Theory by Urie Bonfenbrenner.

How much mental effort did you invest to complete this task? (please circle)

1---2---3---4---5---6---7---8---9

very, very low mental effort  low mental effort  moderate mental effort  high mental effort  very, very high mental effort
Q 3a. What system impacts on the child due to changes in their environment over time?

3b. How much mental effort did you invest to answer this question? 
(please circle)

1---------2---------3---------4---------5---------6---------7---------8---------9
very, very low mental effort
low mental effort
moderate mental effort
high mental effort
very, very high mental effort

Q 4a. Extended family such as grandparents who visit on a fortnightly basis have an indirect impact on a child’s development. What system would this refer to?

4b. How much mental effort did you invest to answer this question? 
(please circle)

1---------2---------3---------4---------5---------6---------7---------8---------9
very, very low mental effort
low mental effort
moderate mental effort
high mental effort
very, very high mental effort

Q 5a. Which system involves values, customs, beliefs and laws shared by one’s culture?

5b. How much mental effort did you invest to answer this question? 
(please circle)

1---------2---------3---------4---------5---------6---------7---------8---------9
very, very low mental effort
low mental effort
moderate mental effort
high mental effort
very, very high mental effort
Q 6. A homework centre in the local community has closed down due to lack of funding. What system does this correspond to?

Please explain your response.

6b. How much mental effort did you invest to answer this question? (please circle)

1------------2----------3--------4--------5--------6--------7--------8--------9

very, very low mental effort
low mental effort
moderate mental effort
high mental effort
very, very high mental effort

Q 7. Television advertising that promotes Madagascar 2 toys in a ‘McDonald’s Happy Meal’ refers to the indirect influence of which system?

Please explain your response.

7b. How much mental effort did you invest to answer this question? (please circle)

1--------2--------3--------4--------5--------6--------7--------8--------9

very, very low mental effort
low mental effort
moderate mental effort
high mental effort
very, very high mental effort
Q 8. When reading the information provided, please explain what you did to help you learn the material
Appendix F

Information provided to participants

Experiment 1
Dear Participant,

Thank you once again for participating in the study conducted in EDFE101 approximately 2-3 weeks ago. The study was investigating aspects of cognitive load theory (CLT). The following information explains in more detail what the study is investigating plus some tips are provided to help you to manage aspects of cognitive load in your future learning at university.

Cognitive Load Theory

Cognitive Load Theory (CLT) is a theory of learning that developed out of direct examination of human cognitive architecture. John Sweller (from University of NSW) and his colleagues saw the examination of cognitive structures as crucial to understanding how humans learn and ways to improve our limited working memory capacities. CLT has generated a set of principles that result in more efficient learning by designing instructional materials that compliment the structure of human memory. (Chapter 6 of your textbook for EDFE101 discusses memory systems and makes mention of cognitive load theory.)

CLT is based on 25 years of largely experimental research throughout Australia, Europe and North America (see Chandler and Sweller, 1991; Kalyuga, Chandler and Sweller, 2000; Paas, 1992; van Merrienboer & Ayres, 2005; Mayer, 2004; Moreno, 2006; Sweller, 1999; Sweller & Chandler, 1994; Van Gog & Paas, 2006). As a result, the theory has evolved with a set of universal principles and guidelines that aim to reduce the load caused by poor design of instructional materials. Some of the effects that have emerged from CLT research include ‘worked examples’, ‘split-attention’, ‘modality’, ‘expertise-reversal’ ‘redundancy’, ‘goal free effect’, ‘completion problem’ and ‘imagination’.

My PhD Study in which you participated
In the experiment I ran, which you were a participant, you were randomly allocated to one of 3 groups:

**Group 1** - received the information re: Ecological Systems Theory (Chapter 11 of your textbook) in a similar format to the textbook.

**Group 2** - also received the information that Group 1 received BUT were given some tips on how to manage the cognitive load imposed by needing to integrate/ link the text with the diagram.

**Group 3** - the diagram and text (as provided to Groups 1 and 2) was integrated using cognitive load principles.

According to Cognitive Load Theory, Group 3 should be more efficient at learning the material because they do not need to link the text with the diagram (as it has been done for them). This is referred to as the ‘split-attention effect’ and basically it claims Groups 1 and 2 had more pressure on their short-term memory.

The results of my experiment show that Group 3 had significantly better performance scores than Groups 1 and 2. This validates that the split attention effect existed in the instructional materials. Interestingly, Group 2 slightly outperformed Group 1. This leads me to further questions about how the instructional guidance (tips) might be improved for students to integrate materials and in turn improve their performance.

**Tips on how to manage your cognitive load**

**Tip 1:** Manage split attention by integrating the text with a diagram.

When reading, it is annoying when you have to turn a page to search for the text that accompanies a picture or graph or when you have to read over a page to make sense of the graph, constantly needing to refer to the graph. When rotating between each your working memory complains about overload. This is due to the search and match procedure that you need to use that allows you to make sense of the information. So next time you are revising for an exam or trying to learn the contents of a diagram, try and integrate the information to make sense of it. E.g., write around the diagram, add some arrows linking important information with corresponding aspect of the diagram.
For example, look at the next two diagrams, one has the information separate, the other has it integrated. Chandler, and Sweller (1991) found greater performance for those exposed to Figure 2, as the pressure on short term (working) memory was reduced and their efforts could be focussed on learning the material rather than trying to link text and diagram.

Test:  
To test Insulation Resistance from conductors to earth

How conducted: i) Disconnect appliances and busways during these tests. Make sure main switch is "on" and all fuses are "in". Remove main earth from neutral bar and set meter to read insulation. Connect one lead to earth wire at MCB bar and take first measure by connecting the other lead to the active. Take next measure by connecting the lead to the neutral.

    ii) If resistance is not high enough in either of the two tests in i) then measure each circuit separately.

Results required: i) At least One Megohm

    ii) Same result as i) above

Figure 1: Split-attention instructions on tests of electrical resistance for installation testing (Source: Chandler & Sweller, 1991)

Physical integration is important if the each source of information is unintelligible in isolation.
Figure 2: Integrated instructions on tests of electrical resistance for installation testing  
(Source: Chandler & Sweller, 1991)

**Note:** Integrating text can improve study skills but only if the text and diagram are unintelligible on their own! Simply integrating information for the sake of integrating is not necessary if you can interpret the diagram without text or if the written material is easy to understand without use of a diagram.

**Tip 2:** Manage split attention by using arrows or circles as cues to draw attention to important verbal material presented in text or in narration. Add cues, signals, circles to diagrams or text.

**Tip 3:** Manage split attention by using bolding, italics, headings, organisers etc when you are writing lengthy and complex study notes, lecture notes. This draws attention to the key words that assist you remember and understand the material
Signals in text (bold, underline, headings) are similar to arrows and circles used to focus attention in diagrams. Group 2 were encouraged to highlight, number the systems and try and integrate text with the corresponding area of the diagram.

*Other general tips to manage cognitive load:*

- Focus on the lecturer if the content on powerpoint slides is identical to what they are saying. By trying to attend to both you are overloading your memory. In this situation, it’s best to listen and make notes at the end.
- If the content of the slides is in summary form, download a copy (if able) prior to the lecture so you can write on the notes as you listen to the lecture rather than trying to write it all down whilst the lecture is taking place.

*When presenting at university, it may be helpful to:*

- Provide your classmates with a summary of issues you are going to present, rather than a handout of your script. This minimises the need for them to take notes so they simply listen to what you have to say and can refer to their notes at a later stage. By writing notes, it interrupts their processing of the information as it requires resources to write the notes.
- This may also be the case for powerpoint slides – ensure your slides are summary points, rather than large amounts of information where one is tempted to read and you are tempted to read as they are presented.

(All tips are adapted from examples provided in Clark, Ngyuen & Sweller, 2006 & Sweller, 1999).

**References**

Some useful references to further examine aspects of CLT include;


Appendix G

Instructional Materials for Experiment 2

Group 2

Note: Whilst printed on two sheets of A4 paper in the Appendix, these materials were presented to the students on one A3 sheet of paper. The instructions were attached to the A3 page.
Completing the instructions below will help you to learn the information presented on the A3 page more effectively by making efficient use of your working memory.

7. Before you read the information in detail, match the text with the diagram by drawing a circle around each paragraph on the right hand of the page (which explains each system, eg., Microsystem, Mesosystem, Exosystem, Macrosystem, and Chronosystem) and drawing an arrow to link it to its corresponding place in the diagram. The first one has been done for you.

8. Then, number each system in sequence (eg., 1. Microsystem, 2. Exosystem, 3. Mesosystem, etc) on both the diagram and the text. The first one has been done for you.

9. While you are reading, highlight or underline key words that relate the information with the diagram (one has been done for you).

Now go back and study the content for the remainder of the time…..
Ecological Systems Theory (by Urie Bronfenbrenner)

The child is viewed as developing within a complex system of relationships that are shaped by influences at many levels within the surrounding environment. The theory focuses on the context or the environment in which children develop, rather than on development itself. The environment is regarded as a series of structures (illustrated as layers) that are embedded in one another. From this perspective each layer in the child’s environment is seen as exerting a powerful influence on development. Figure 1 below illustrates the layers of the theory;

Figure 1 – Ecological Systems Theory
**Microsystem** – Immediate context where the child develops: Home (including parents, siblings) school (including friends, peers) and the local community. This setting is where the majority of research into child development takes place.

**Mesosystem** – connections between the microsystem. For example, the way the family interact with the school will demonstrate the influence that both environments have on academic progress. When learning is valued in the home and effective communication with the school, opportunities for success are likely to be increased.

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**Macrosystem** – Values, Beliefs, customs and laws shared by the culture. These factors all contribute to the functioning of various systems such as the family, the legal system and the education system.

**Chronosystem** – Changes in the child’s overall environment that occurs across time. These changes may produce changes that significantly impact on a child’s development. Examples include birth of a sibling, moving house, parent divorce.

Bronfenbrenner’s model allows one to develop a more comprehensive picture of child development by taking into account the child, the immediate setting in which interactions occur as well as the variety of other contexts that influence development. It emphasises the dynamic nature of a child’s development through the integration of a complex array of factors.

Appendix H

Post Test Materials for Experiment 2
**Question 1.** How much mental effort did you invest to learn this material? (please circle)

1------------2------------3------------4------------5------------6------------7------------8------------9

very, very low mental effort
low mental effort
moderate mental effort
high mental effort
very, very high mental effort

Please Turn Over ➔
**Question 2.** Please complete the diagram below to provide a representation of the Ecological Systems Theory by Urie Bonfenbrenner.

How much mental effort did you invest to complete this task? (please circle)

1---------2---------3---------4---------5---------6---------7---------8---------9

very, very low mental effort  low mental effort  moderate mental effort  high mental effort  very, very high mental effort
Q 3. What system impacts on the child due to changes in their environment over time?

Q 4. Extended family such as grandparents who visit on a fortnightly basis have an indirect impact on a child’s development. What system would this refer to?

Q 5. Which system involves values, customs, beliefs and laws shared by one’s culture?

Q 6. A homework centre in the local community has closed down due to lack of funding. What system does this correspond to?

Please explain your response.

Q 7. Television advertising that promotes Madagascar 2 toys in a ‘McDonald’s Happy Meal’ refers to the indirect influence of which system?

Please explain your response.

Q 8. How much mental effort did you invest to answer these questions? (please circle)

1 --------- 2 --------- 3 --------- 4 --------- 5 --------- 6 --------- 7 --------- 8 --------- 9

very, very low mental effort
low mental effort
moderate mental effort
high mental effort
very, very high mental effort
Q 9. When reading the information provided, please explain what you did to help you learn the material
Appendix I

*Instructional Materials for Experiment 3*

**Part 2**

Note: whilst printed on two sheets of A4 paper in the Appendix, these materials were presented to the students on one A3 sheet of paper.
Kohlberg’s Stages of Morality

Kohlberg (1969, 1980), whose research closely follows Piaget’s pioneering investigations, studied moral development by posing moral dilemmas to groups of children, adolescents and adults. These dilemmas took the form of stories, among the best known of which is the story of Heinz (Kohlberg, 1969). Paraphrased here:

Heinz’s wife was dying of cancer. One special drug recently discovered by a local pharmacist might save her. The pharmacist could make the drug for $200 but was selling it for 10 times that amount. So Heinz went to everyone he knew for the money but could only scrape together $1000. He asked if he could pay the rest later but the pharmacist refused. Desperate, Heinz broke into the pharmacy and stole the drug for his wife? Should he have done that? Why?

Children’s responses suggest three levels in the development of moral judgements, each consisting of two stages of moral orientation (shown in Figure 1). Three levels are sequential, although succeeding levels never entirely replace preceding ones, making it almost impossible to assign ages to them.

Figure 1. Kohlberg’s levels of Morality

(Adapted from: LeFrancois, 1995)
Preconventional Level
At the preconventional level, children’s judgement of right and wrong takes one of two orientations. In the first (stage 1), children believe that evil behaviour is that likely to be punished and good behaviour is based on obedience. Thus children do not evaluate right or wrong; judgement is based solely on consequences to the child.
The second preconventional moral orientation (stage 2) is a hedonistic one in which children interpret good as that which is pleasant and evil as undesirable consequences. Children will go out of their way to do something good for someone if they themselves will benefit from the deed.

Conventional Level
The second level, morality of conventional role conformity, reflects the increasing importance of peer and social relations. Stage 3 is defined as morality designed to maintain good relations. Hence moral behaviour receives wide approval from significant people; parents, teachers, peers and society at large.
Stage 4, conformity to rules and laws, is also related to children’s desire to maintain a friendly status quo. Thus conformity to law becomes important for maintaining adults’ approval.

Postconventional Level
At the highest level, the postconventional level, individuals begin to view morality in terms of individual rights and as ideals and principles that have value as rules or laws apart from their influence on approval (stage 5). As noted, stage 5 moral are judgements are rare, even for adults.
Stage 6 judgments are based on fundamental ethical principles, are even rarer. Colby and Kohlberg (1984) suggest that there is some doubt as to whether or not stage 6 should even be included as a stage in moral development.

Kohlberg’s early research suggests that children progress through the stages of moral development in predictable sequence and at roughly the same ages. Theoretically this makes sense because moral judgments are essentially cognitive and would therefore be expected to reflect the level of cognitive development. (Source: Lefrancois, 1995)
Appendix J

Post Test Materials for Experiment 3

Part 2
**Question 1.** Please complete the diagram below to provide a representation of Kohlberg’s ‘Stages of Morality’ theory.

**Q2.** Which stage correlates with conformity to law as important for maintaining the approval of adults?

**Q3.** What stage relates to fundamental ethical principles?
Q4. If a child responds to the Heinz scenario with “If he steals the drug, he will go to jail”, which stage might this place the child?

Q5. How might a child operating at the conventional level respond to the Heinz scenario (ie. should he have broken into the pharmacy and stole the drug? Why or why not?)?

Q6. How might a adult operating at a post conventional level respond to the Heinz scenario (ie. should he have broken into the pharmacy and stole the drug? Why or why not?)?

Q7. What did you do with the information on your A3 page to help you to learn?

Q8. Did you demonstrate this on the page?
Q8a. Did you apply the principles asked in the first learning phase (circle, link information in text with diagram, number stages etc.)? If no, why not?

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........................................................................................................................................................................................................
........................................................................................................................................................................................................
........................................................................................................................................................................................................

Thank you for your time. Please put all paperwork inside the A3 page.