

CONCEPTUAL CHANGE WITH REFUTATIONAL MAPS

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ABSTRACT

The purpose of this research was to explore the effect of studying refutational maps on conceptual change. Refutational maps are diagrams that explicitly present correct conceptions and commonly held misconceptions. A sample of 120 participants was randomly assigned into three groups: a refutational map group, a refutational text group and a non-refutational text group. A posttest was conducted to examine participants' performance on free recall and learning transfer measures. Results revealed that the refutational map group outperformed the other two groups on the free recall test. On the transfer essay test, the refutational map group outperformed the non-refutational text group but was not statistically detectably different from the refutational text group. On the transfer multiple-choice test, differences in the mean scores of the three treatment groups were not statistically detected. The research also found that need for cognition and logical thinking predicted the acquisition of scientific concepts, and students with lower logical thinking ability benefited more from learning the refutational map. These findings provide an insight into prior research on conceptual change and have instructional implications for incorporating effective cognitive tools in science classrooms.

Key words: refutational map; conceptual change; need for cognition; logical thinking

DEDICATION

To my parents

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CHAPTER 1: INTRODUCTION

1.1 Rationale

Over the past decades, there has been increasing concern regarding the effect of students' alternative conceptions or misconceptions on learning natural science (Chambers & Andre, 1997). Some research has revealed that students' misconceptions about natural phenomena are likely to impede the acquisition of scientific concepts (Chambers & Andre, 1997; Duit & Treagust, 2003). It has been found that students have difficulties in learning new conceptions because they rely on preexisting misconceptions to make sense of newly learned science concepts (Zietsman & Hewson, 1986). In addition, students' misconceptions are robust and resist instructional change, and many students fail to abandon misconceptions despite having successfully completed science courses (Driver & Easley, 1978). Therefore, an essential mission of science education is to help students overcome misconceptions and develop valid systems of scientific knowledge (Onder & Geban, 2006). Traditional expository writing in science textbooks, however, has shown little power to facilitate conceptual change because it mostly explains concepts and does not present the inconsistency between commonly held misconceptions and scientific viewpoints (Hynd & Alvermann, 1986). Refutational text, which presents and refutes misconceptions, has been devised to produce cognitive conflict and promote conceptual change (Guzzetti, 2000; Hynd & Alvermann, 1986).

Are there ways to enhance refutational presentations so that cognitive conflict is more reliably elicited and conceptual change is obtained with greater certainty? Although texts are primary tools for learning, many students have difficulties in effectively

processing and comprehending traditional textbooks (Oliver, 2009). In fact, text comprehension is a complex and dynamic process which requires readers to integrate their prior knowledge with textual information to construct a mental representation of the text (Anderson & Botticelli, 1990; van Broek & Kendeou, 2008). To address this concern, several techniques for structuring text, such as inserting headings or questions into text, have been employed by researchers to help students process and construct knowledge (Brooks, Dansereau, Spurlin, & Holley, 1983; Reinking, Pickle, & Tao, 1996). Furthermore, graphic organizers have been widely applied to facilitate text comprehension and retention. One type of graphic organizer called a concept map is reported by researchers to be an effective tool for helping readers understand relationships between concepts presented in science texts (Oliver, 2009). Another type of graphic organizer called an argument map transforms the arguments in text into a spatial representation and functions as a retrieval scheme to increase subsequent memory for arguments (Dwyer, Hogan, & Stewart, 2010; van Gelder, 2002).

As mentioned above, research has shown that refutational texts are beneficial for changing students' misconceptions and graphic organizers are helpful for constructing and retaining new knowledge. Therefore, this thesis investigated the effectiveness of a diagrammatic technique for presenting refutational text. Specifically, it explored whether refutational maps, which not only present common misconceptions but also display the embedded structure of refutational texts and clarify implicit logical relationships among concepts, could combine the features of refutational texts and graphic organizers to foster conceptual change.

In addition, the study examined need for cognition, a psychological construct

measured by a self-report questionnaire, as a potential factor influencing students' cognitive engagement with refutational texts and refutational maps (Cacioppo, Petty, Feinstein, & Jarvis, 1996). Need for cognition has been found to be related to efficiency in processing conflicting information (Kardash & Scholes, 1996). Because a large number of studies in science education have reported significant relationships between formal reasoning ability and students' achievement (Lawson, 1985; Nagy & Griffiths, 1982), the research also examined the effect of logical thinking ability as an indicator of students' cognitive development level. The level of logical thinking ability is expected to be an important factor in acquiring an understanding of scientific concepts (Gönen, 2008).

1.2 The Experiment

A total of 120 participants who demonstrated misconceptions about Newtonian principles of motion during the screening test took part in this research. After completing the demographic questionnaire, the 18-item Need for Cognition Scale and the Test of Logical Thinking, they were randomly assigned into one of the three groups: a non-refutational text group, a refutational text group, and a refutational map group. After reading the treatment-specific materials, the three groups were then asked to complete a free recall test, a transfer essay test and a transfer multiple-choice test about concepts introduced in their previously studied readings. Multiple types of data were collected in this study, including: (1) demographic data, (2) scores on the need for cognition scale, (3) scores on the test of logical thinking, (4) reading time, (5) scores on the free recall test, (6) scores on the transfer essay questions and (7) transfer multiple-choice questions.

1.3 Research Questions

The experiment was designed to address the following research questions:

1. Does explicit discussion of misconceptions lead to better learning outcomes?
2. What are the cognitive effects of studying refutational maps? Specifically, do students who study the refutational map show conceptual change similar to students who study refutational text?
3. Do individual differences in need for cognition influence students' conceptual change?
4. Do individual differences in logical thinking ability influence students' conceptual change?
5. Is the association between logical thinking ability and conceptual change moderated by type of presentational format?

1.4 Findings

The findings of this study suggested the effectiveness of the refutational map to facilitate free recall and promote conceptual change. Specifically, it was found that participants studying the refutational map outperformed those studying non-refutational and refutational text in the free recall test. In addition, the results showed that participants studying the refutational map achieved the highest scores among the three groups in the transfer essay test, but only the difference of scores between the refutational map group and the non-refutational text group was statistically detectable. No differences were

detected among the three reading groups for the transfer multiple-choice test.

Furthermore, the study indicated that need for cognition and logical thinking ability were indicators of learners' achievements in the outcome tests. For the transfer essay scores, an interaction was found between logical thinking ability and presentation format.

These results have instructional implications for integrating refutational maps as effective cognitive tools into classroom settings to scaffold teaching and learning science. Importantly, teachers could employ refutational maps in science education to shorten the gap between lower and higher logical thinkers.

CHAPTER 2: LITERATURE REVIEW

2.1 Reading for Conceptual Change

2.1.1 Misconceptions in Learning

Research has established that students often develop perceptions about natural phenomena before they are taught in classrooms (Posner, Strike, Hewson, & Gertzog, 1982). However, these notions may be inconsistent with current scientific viewpoints. In such cases these prior beliefs have been referred to as *misconceptions* (Fisher, 1985). Other terms frequently utilized by researchers in the literature to refer to misconceptions are, to name a few, alternative conceptions, naïve conceptions, alternative frameworks or naïve perceptions (Arnaudin & Mintzes, 1985; Carlsen & Andre, 1992; Linder, 1993; Wandersee, Mintzes, & Novak, 1994). As a product of learners' efforts to make sense of the world, misconceptions pervade almost every subject area, particularly science (Janiuk, 1993; Maria, 2000).

During the past three decades, owing to the popularity of constructivist learning theory that emphasizes the interaction between previous and new conceptions in knowledge construction, there has been increasing concern regarding the effect of prior knowledge, including alternative conceptions or misconceptions, on learning natural science (Chambers & Andre, 1997; Duit & Treagust, 2003). Some research indicates that misconceptions are barriers to learning science. Students have difficulties in acquiring new conceptions because they rely on preexisting misconceptions derived from previous experiences to make sense of science concepts to be learned (Zietsman & Hewson, 1986). What's more, students' misconceptions reflect longitudinally deeply-rooted personal experiences and are often too robust to yield to instructional change. Many students

cannot overcome their misconceptions despite having successfully completed science courses (Driver & Easley, 1978; Guzzetti, Snyder, Glass, & Gamas, 1993; Kikas, 1998; Bahrick, 1979; Fisher, 1985). Therefore, misconceptions to a large degree interfere with students' learning of science.

2.1.2 Conceptual Change Model

Having recognized that alternative conceptions have an impact on knowledge acquisition, Onder and Geban (2006) contended that a key feature of successful science education could be framed as identifying and remediating misconceptions to make better sense of the physical world. As indicated by Smith, Blakeslee, and Anderson (1993) and Yuruk (2007), meaningful learning of science, in addition to simply incorporating new information into a current knowledge system, involves a dynamic process of realigning, reorganizing or replacing preexisting conceptions to accommodate new information. This process has been called conceptual change. To put it simply, conceptual change is a learning process in which learners' misconceptions are transformed to valid scientific conceptions.

Piaget (1970) introduced three terms to describe fundamental processes contributing to conceptual change: assimilation, accommodation and equilibration. Assimilation refers to the process of taking new concepts into a current knowledge system. When learners experience something foreign to or inconsistent with their existing mental structures, a state of cognitive disequilibrium emerges. Equilibrium can be restored by accommodation, which modifies pre-existing mental structures to incorporate new ideas (Dykstra, Boyle, & Monarch, 1992). Piaget emphasized the balancing of assimilation and

accommodation as self-regulatory mechanisms that strive to establish equilibrium.

Regarding the phase of conceptual change, Kuhn (1970) defined the process of doing normal science as analogous to assimilation denoted by Piaget, accreting knowledge within a paradigm without changing the underlying conceptual structure. In the same way, scientific revolution occurs as a discipline develops new and fundamentally different paradigms. This is parallel to accommodation in Piaget's theory.

Drawing an analogy between Piaget's concepts of assimilation and accommodation and Kuhn's (1970) descriptions of normal science and scientific revolution, Posner, Strike, Hewson, and Gertzog (1982) proposed a *Conceptual Change Model (CCM)* to describe how learners change their misconceptions through an interaction between previous and new concepts. Posner et al. (1982) discussed four conditions necessary for conceptual change to take place: (1) Learners must begin to realize that their existing conceptions cannot help them solve a collection of problems. (2) Learners can easily make sense of new theories; ideally, they can construct a coherent representation of the theories' concepts as tools for thought (Uzuntiryaki & Geban, 2005). (3) The new concepts must at least appear to be a plausible choice to better solve problems at hand. (4) The new concepts should suggest the potential possibility to open up new areas of inquiry and can be used to explain more events or phenomena. In short, the above four conditions can be summarized as dissatisfaction, intelligibility, plausibility and fruitfulness, respectively.

The key concepts of the conceptual change model are status and conceptual ecology (Murphy & Mason, 2006). Status indicates the degree to which a new conception is productive. The more a learner finds a theory intelligible, plausible and fruitful, the

higher is its status (Yuruk, 2007). Another component emphasized by Posner et al. (1982) is conceptual ecology which refers to the collection of learners' epistemological commitments, anomalies, analogies, metaphor, metaphysical beliefs, competing concepts, and so on. Conceptual ecology, serving as the context in which the conceptual change takes place, influences the process of conceptual change (Bulunuz, 2007; Toulmin, 1972; Kelly & Green, 1998).

2.1.3 Conceptual Change Strategies

Several strategies have been cultivated to achieve conditions for conceptual change. One of the main emphases lies in the innovation of text structures. In science education, text has been regarded as an essential medium for acquiring disciplinary knowledge (Ariasi & Mason, 2010; Diakidoy, Kendeou, & Ioannides, 2003). Therefore, features of text are theorized to facilitate conceptual change. Specifically, effective text formats should prompt readers to activate, explain, test and revise their conceptions about the phenomenon being examined (Hennessey, 2003).

Traditionally, texts in science textbooks are mostly written in expository styles which describe concepts and do not present the concepts as conflicting with commonly held misconceptions (Hynd & Alvermann, 1986). Such traditional texts may not be effective in raising students' awareness of an inconsistency between their naïve perceptions and newly presented scientific concepts (Guzzetti et al, 1993, Woloshyn, Paivio, & Pressley, 1994). Therefore, researchers focusing on text-based methods of facilitating conceptual change have adapted traditional texts in an attempt to create more effective text formats.

In the field of science education, the conceptual change model proposed by Posner et al. (1982) has guided instruction to help students transform their misconceptions to more accurate conceptions. In order to achieve this transformation, *cognitive conflict* is frequently stressed as a necessity (Akgün & Deryakulu, 2007; Chan, Burtis, & Bereiter, 1997). Cognitive conflict corresponds to Piaget's notion of disequilibrium and the condition of dissatisfaction proposed by Posner et al. (1982). Based on the conceptual change model, two versions of alternative text formats hypothesized to cause cognitive conflict are *refutational text* and *conceptual change text*, developed by Roth (1985).

As defined by Hynd and Alvermann (1986) and by Alvermann and Hague (1989), refutational text is a text structure that directly contrasts scientific concepts with commonly held misconceptions. Basically, in refutational texts, there are two key parts which can be presented in any order: the explication of an inaccurate conception and a refutation of that misconception (Guzzetti, 2000). Refutational text has been described by Guzzetti (2000) as one of the most effective means of producing cognitive conflict to facilitate conceptual change. Conceptual change text differs from refutational text in that, additionally, readers are asked to make predictions about a particular situation. Both conceptual change text and refutational text explicitly state the misconceptions that may be held by readers, which can cause them to experience cognitive conflict.

2.1.4 Efficacy of Refutational Texts

A host of studies have explored the effectiveness of refutational texts across various grade levels in science education. For example, Hynd and Alvermann (1986) compared the effect of non-refutational and refutational texts on college students' conceptual

change regarding Newtonian mechanics. They found that refutational text more effectively helped students relinquish their misconceptions about motion theory. Palmer (2003) asked 36 ninth-grade students to read either a text consisting of didactic explanation of ecological role or a text directly refuting commonly held misconceptions. The post-interviews revealed that students who read refutational text outperformed those who read traditional non-refutational text. Diakidoy et al. (2003) also discovered that reading refutational text was more effective in facilitating sixth-graders' acquisition of scientific energy concepts than reading a non-refutational, expository passage.

In addition, qualitative evidence has been provided by Hynd (2001) who summarized high school physics students' reaction to different types of texts related to projectile motion, including narratives, non-refutational and refutational texts. She found that refutational texts are perceived as persuasive and students prefer refutational texts to other formats. Their comments about refutational texts could be summarized as having the following features: (1) Discrepancy with belief: Students could recognize the inconsistency between the text' interpretation and their own. (2) Understandability: Students could easily make sense of what the text talked about. (3) Credibility: Students wanted to believe what they read because explanations presented in the text were related to their everyday experiences. (4) Usefulness: The information discussed in the text could be used to explain other phenomena in life and could lead to new discoveries. (5) Repetitiveness: Students could fit information learned from this text into what they learned before from other sources. (6) Relatedness: Students could identify how the misconceptions discussed in the text in most cases fit what they believed before. These features summarized from high school physics students' comments about refutational

texts are in line with the notions of dissatisfaction, intelligibility, plausibility and fruitfulness in the Conceptual Change Model proposed by Posner et al. (1982). Also, according to van de Broek and Kendeou (2008), refutational texts provide an optimal context where co-activation of the incorrect and scientific conceptions takes place. Co-activation leads students with misconceptions to cognitive dissonance and knowledge revision. Therefore, refutational texts should be a powerful tool to promote conceptual change (Hynd, 2001).

In addition, Ariasi and Mason (2010) developed a more comprehensive and in-depth analysis of cognitive processing underlying reading refutational and non-refutational texts by observing readers' ocular behaviors. Ariasi and Mason (2010) randomly divided 40 Italian students from a public university into two groups, an expository text study group or a refutational text study group, and investigated students' allocation of visual attention during text reading by tracking their eye movements. In addition to the finding in line with most previous studies that students reading refutational text performed better than those reading expository text, it was also found that a shorter time was taken to fixate on the refutational segments than the corresponding manipulated segments in expository text. Overall, either during the initial processing of the text or during the second-pass look-back, compared with those reading expository text, students learning refutational text fixated more time on the segments discussing scientific concepts which were identical in both texts. Regarding the findings, Ariasi and Mason (2010) presumed that reading refutational segments could help readers speed up cognitive processing by externally activating their relevant prior knowledge, though incorrect, and the faster link between text elements and mental structures avoids a breakdown during the process of

comprehension (Fontanini, 2004). When they then proceed to the segments presenting scientific concepts, the co-activation of inaccurate and accurate ideas occurs, which raises a conceptual inconsistency and slows down cognitive processing for argumentative thinking. According to van de Broek and Kendeou (2008), the slowdown indicates refutational text readers' cognitive efforts to "repair the conflicts and create coherence" (p. 344). After the first-round reading, refutational text readers reallocated their visual attention to the scientific theories because they may have realized the necessity to elaborate on these crucial parts to address the cognitive conflict. Though the pattern of cognitive processing was drawn from a small number of participants, the study, to some extent, sheds light on the effect of refutational texts on supporting and driving readers' visual attention during reading (Ariasi & Mason, 2010).

What's more, Guzzetti et al. (1993) and Guzzetti (2000) concluded that effects of refutational text on conceptual change could be sustained over time compared to effects of non-refutational text, cooperative discussion or demonstration.

2.1.5 Concerns on Text Reading

Educational texts are meant to be read and comprehended so their gists can be retained (Dwyer et al., 2010). However, many students have difficulties in comprehending and recalling the meaning of texts, especially expository materials (Griffin & Tulbert, 1995; Taylor, 1985; Winograd, 1984). That's because comprehension of textual information is a complicated and dynamic process which requires the mobilization of existing knowledge to encode the written information into meaningful units that are transformed and integrated with existing knowledge (Anderson & Botticelli,

1990). What's more, though memorization involves superficial learning (Kintsch, 1993), in many cases students find it is too memory-intensive to remember everything from lengthy texts, which may result in omission of key points that are important for correct and thorough understanding. Also students usually fail to recall and further apply what they read from a text because they are not able to identify the gist of the text or they could not build meaningful representations of information to facilitate the process of transferring scattered words or sentences stored in short-term memory into long-term memory (Craik & Lockhart, 1972; Dwyer et al., 2010; Shimmerlik, 1978).

To deal with such constraints on learning from linear texts, researchers have employed organizational strategies to help learners manipulate information during the encoding process by providing a retrieval scheme to aid long-term retention (Dwyer et al., 2010; Shimmerlik, 1978). Moreover, in attempts to improve reading efficiency, researchers have devised several techniques for structuring text that help students construct knowledge. For example, inserting questions into text can increase recall and comprehension of textual information (Reinking et al, 1996). Other examples are using headings to help readers process complex text materials (Brooks et al., 1983) and using bold typeface to alert learners to attend to those highlighted key words (Robinson & Katayama, 1999). As well, graphic displays have been reported as an effective diagrammatic technique for presenting textual information as discussed in the next section.

2.2 Reading with Graphic Displays

2.2.1 Kintsch's Model of Text Comprehension

Text comprehension takes place at different levels. Kintsch's model of text comprehension differentiates three levels involved in learning from texts. The first level of comprehension concerns the structure of sentences, such as linguistic relations between words and phrases. Second, at the *textbase* level of comprehension, emphasis is on the semantic and rhetorical structure of texts, such as the network of related propositions (Hofman & Oostendorp, 1999). Kools, van de Wiel, Ruiter, Crüts, and Kok (2006) indicated that on the level of textbase understanding, readers may remember parts of a text but not necessarily understand them all. Therefore, learning at the level of the textbase mainly contributes to reproduction of a text and, by itself, allows only a superficial level of comprehension (Kintsch, 1993). In contrast, constructing a *situation model* requires deeper understanding and builds structures that allow one to be able to apply information acquired from the text and integrate the newly-learned information with prior knowledge to explain and address new issues (Kintsch, 1993). Therefore, the construction of a situation model is necessary for such complex tasks as reasoning and problem solving.

With regard to Kintsch's three levels of comprehension, Kools et al. (2006) contended that the process of constructing mental representations is influenced by the coherence of a text. Kintsch and van Dijk (1978) claimed that a text has two levels of structure: *microstructure* and *macrostructure*. The former represents a network of propositions, and the latter reflects the main idea or gist of a text. Macrostructure is built on the basis of microstructure by applying "macrorules", including deletion, generalization and construction (Kintsch & van Dijk, 1978; van Dijk, 1980). In brief, deletion means selecting relevant propositions needed for text interpretation and then

deleting irrelevant ones. Generalization rules make a proposition more abstract by deleting redundant information (Fontanini, 2004). Finally, construction refers to synthesizing micropropositions into a single proposition denoting a global fact or category. Allowing for the internal text structures, therefore, the coherence of a text requires not only that the relations among sentences are explicitly presented for micro level, but also that the sections of a text are clearly and logically related to each other and to the overall topic for macro level (Hofman & Oostendorp, 1999; Kools et al., 2006).

From a practical perspective, Kintsch's model helps researchers analyze students' underlying comprehension of texts and also has some instructional implications for text-based design. For example, Kintsch (1989) summarized the results of a number of studies and found that readers, either school children or even more advanced students, have difficulties in macro-processing expository texts, that is, transcending microstructure to macrostructure, mainly because they cannot discriminate important information from irrelevant propositions to generalize and construct a gist of a text (Markrman, 1979), or they become too focused on the meaning of specific sentences rather than on extracting the global meaning (Taylor & Samuels, 1983).

Surprisingly, the findings of a study conducted by Kools et al. (2006) showed a significant effect of graphic organizers on fostering deeper comprehension on both micro and macro levels. Specifically, graphic organizers that clarify relations among concepts not only facilitate readers in grasping both the big picture and details of a text at the textbase level, but also help them construct a situation model of the global and local text content. Kools et al. (2006) hypothesized that graphic organizers may provide a retrieval scheme to effectively facilitate recall and comprehension on the micro-level (Dee-Lucas

& Larkin, 1995). It is also likely that graphic organizers which elicit the macrostructure of a text enable more cognitive capacity to be spared for processing information on the micro-level without challenging the limitation of working memory, and leave enough capacity and time to build a situation model through the integration of micro-level and macro-level information in the organizers.

2.2.2 Schema Theory

Apart from Kintsch's model of text comprehension, schema theory also helps researchers gain more insights on how knowledge is organized, encoded and retrieved for later recall and comprehension (Al-Issa, 2006). The term *schema*, originally introduced by Bartlett (1932), refers to a mental structure that represents general knowledge derived from past experience. And each schema, as an abstract information unit, consists of slots into which relevant and specific newly incoming information can fit (Anderson, Spiro & Anderson, 1978; Bartlett, 1932). A schema is not static but modifiable and dynamic. Thus, during the process of learning, schemas stored in memory help readers construct interpretations of new information and serve as retrieval mechanisms for later recall. During this process, an existing schema can be extended and modified by assimilating and accommodating new information provided in a text.

Schema theory indicates that learning involves an interaction between texts and readers, and emphasizes the role of background knowledge in recall and comprehension. Anderson et al. (1978) raised the point that information that matches a superordinate schema is regarded to be significant and can be better remembered and learned; however, information that does not match is classified as unimportant and may be ignored.

Therefore, the activation of background knowledge or schema in memory is beneficial for effective and efficient integration of prior and new concepts. According to Ariasi and Mason (2010), reading refutational segments presented prior to scientific ideas may be an effective strategy for provoking readers' relevant experience and preparing them for incoming theories.

In addition, schema theory has instructional implications on how texts should be organized to aid comprehension. As indicated by Pehrsson and Denner (1988), it is helpful to learn from materials when implicit organizational structures are made explicit. Kintsch and van Dijk (1978) pointed out that reading comprehension requires readers to construct a mental representation to bridge the text and schemas stored in memory. The faster the link between text elements and mental schemas is created, the less likely that a breakdown occurs during the process of comprehension (Fontanini, 2004). Therefore, such cognitive tools as graphic organizers or other node-and-link displays, which help readers more readily identify the global message as well as logical relations among key ideas that authors intend to convey, can assist readers to construct a coherent mental picture of information in the text and efficiently integrate new information into existing schemas for better comprehension or argumentation (Kintsch & van Dijk, 1978; Mandler & Johnson, 1977; Meyer, 1975; Reznitskaya & Anderson, 2002; Taylor, 1980).

2.2.3 Dual Coding Theory

According to Paivio's dual coding theory, there are two independent but interrelated mental subsystems working simultaneously in human cognition. One stores and processes verbal objects such as text-based linguistic representations, and the other stores and deals

with visual objects such as picture-like representations (Paivio, 1986; Rieber, 1992; Rieber, 1994). The terms *logogens* and *imagens* refer to the units of information in these verbal and visual systems, respectively (Morton, 1979). The modality and size of the units can be changeable, as described by Sadoski, Paivio, and Goetz (1991): “a logogen could correspond to a phoneme, grapheme, morpheme, word, phrase or a larger familiar unit, and an imagen could represent a natural object (or sound, etc.), a part of that object, or a natural grouping of objects” (p. 473).

It is assumed that three levels of processing may occur within the verbal and visual systems: representational processing, referential processing and associative processing. When representational processing occurs, the activation of logogens is directly triggered by verbal stimuli and the activation of imagens is directly triggered by visual stimuli. Referential processing is a cross-system activity that involves connections between the verbal and visual systems. Specifically, the activation of logogens in the verbal system can lead to the activation of imagens in the visual system, and vice versa. In contrast, associative connections refer to intra-system activities. For instance, the word “pineapple” may activate some related words stored in the same verbal system, such as “apple” and “cherry”. Similarly, an image of a “computer” may activate other images in mind like “mouse” or “keyboard”. Therefore, these two coding systems can not only function independently but also provide mutual aid in information processing because the interconnections between the two memory systems develop additional retrieval paths for both verbal and visual information and facilitate transfer learning (Nesbit & Adesope, 2006; Rieber, 1994). Rieber (1992) suggested the application of dual coding theory in the design of visual instruction. One strategy based on this theory is to let students view or

construct concept map in combination with semantically equivalent texts, which may promote cognitive processing of information in both verbal and visuospatial memory (Nesbit & Adesope, 2006).

2.2.4 Visual Argument

Traditionally, people rely on verbal or written expressions for argumentation. Visual representations are also persuasive. Waller (1981) introduced the term *visual argument* to characterize the way visual displays convey information and make inferences in an argument explicit (Vekiri, 2002). Visual argument involves employing a spatial arrangement of text elements to present implicit relations among concepts (Robinson & Kiewra, 1995). For example, words or propositions are usually grouped spatially close to intuitively inform learners of the relevance (Vekiri, 2002). In this way, as indicated by Larkin & Simon (1987), relevant and important information can be easily located in visual displays, and therefore, well-organized graphic representations facilitate information search and extraction. In many cases, instead of being made up entirely of visual elements, some visual arguments incorporate verbal components as a complementary mode of communication to facilitate meaning construction (Birdsell & Groarke, 2007).

Other work in cognitive science indicates that graphic displays not only express information but also guide cognitive activities (Scaife & Rogers, 1996). In particular, learning from symbolic representations can be more effective and efficient than learning from texts in complex tasks because people do not have to mentally engage in extraneous cognitive processes (Vekiri, 2002). For example, while reasoning about a problem using

texts, people have to scan the entire text for a piece of information and then store it in working memory while searching another piece, continuing in this process until all the relevant information is located (Robinson & Schraw, 1994). However, graphic displays in which related parts are nearby or are connected by lines can reduce visual search by allowing learners to directly jump to relevant information. Importantly, graphical representations may function as a memory aid to trigger and aid the recall of a series of relevant knowledge stored in mental schemas to support reasoning during problem solving (Narayanan et al., 2005).

In short, according to the theory of visual argument, graphic displays are as effective as, if not better than, texts. This is because graphic displays explicitly present embedded relations among concepts and, compared to linear text, require fewer cognitive transformations so as not to challenge the limitations of working memory (Vekiri, 2002).

2.2.5 Graphic Organizers with Learning

Graphic organizers were developed based on Ausubel's learning theory that stresses the processes of subsumption. Similar to schema theory, this means that learners usually relate new experiences to previous knowledge, and accordingly subsume that newly incoming information into existing relevant superordinate schemas (Ausubel, 1960). Therefore, prior knowledge is important (Ausubel, 1968). Further, Ausubel (1963) contended that the effectiveness of learning and retaining new information is attributed to whether a cognitive structure is clear and well organized. The advance organizer, which can be introduced prior to new lessons to help learners efficiently bridge what they already know and new information to be learned, is the origin of graphic organizer

(Ausubel, 1960).

A graphic organizer, consisting of spatial arrangements of words or word groups, commonly refers to two-dimensional visual knowledge representations, which display the conceptual organization of text and make embedded among-concepts relations explicit (Alvermann, 1981; Ives & Hoy, 2003; Stull & Mayer, 2007; Winn, 1991). Many researchers have stressed the advantages of incorporating graphic organizers to aid reading comprehension and recall. For example, different from traditional linear text presentation, graphic organizers serve as visual scaffolds to help learners understand and retrieve key points discussed in texts (Oliver, 2009). Also graphic organizers are beneficial for increasing reading efficiency because well-organized visual symbols are easily recognized and its minimum use of text enables information to be quickly scanned into short-term memory in an orderly fashion. Together, these allow new information to be more readily assimilated and accommodated (Ben-David, 2002; Plotnick, 1997).

2.2.6 Concept Map

As a type of graphic organizer, concept maps are effective tools for improving reading comprehension and information retrieval and, particularly, for helping learners visualize and understand relationships between and among concepts presented in texts (Oliver, 2009; Novak & Gowin, 1984; Zeitz & Anderson-Inman, 1992). In addition, concept maps economize the storage and retrieval of information by reducing syntactic complexity and redundancy of textual information (O'Donnell, 1994; Tzeng, 2010). A meta-analysis found that, compared with studying traditional text passages, studying concept maps is somewhat more effective for retaining knowledge (Nesbit & Adesope,

2006).

2.2.7 Argument Map

An argument map is another type of graphic organizer which transforms the arguments in a text into a spatial representation in which related propositions are grouped close to one another and linked by arrows that represent the relations between propositions (van Gelder, 2002). Dwyer et al. (2010) argued that learning text-based arguments is a cognitively demanding process in that readers are supposed to mentally construct arguments by distinguishing and linking statements that support or dispute claims scattered throughout texts. The high degree of attention switching increases readers' cognitive load and impedes meaningful learning (Pollock, Chandler, & Sweller, 2002). Though little research has been conducted to examine the effectiveness of argument maps as learning aids, Dwyer et al. (2010) assumed that presenting the visual structures of arguments as a whole and showing relations among propositions could facilitate logical reasoning. What's more, they believed that an argument map would lower cognitive load because its presentation could remove the need to mentally construct relational structures of arguments while reading argumentative texts. Experiments testing the above assumptions indicated that, in comparison with traditional text-based information delivery methods, argument map reading significantly increases recall of arguments (Dwyer et al., 2010).

2.2.8 Concerns on Learning from Graphical Displays

Despite having been recognized as effective cognitive tools, graphic displays still

place some constraints on reading comprehension. For example, although reading graphic displays may relieve readers from the need to extract subtle meaning structures, it may also deprive readers of initiative in processing study materials and frame the way readers interact with texts (Tzeng, 2010). Moreover, though visualizing ready-made structural displays permits quicker and easier encoding of relational information, it may sacrifice the effortful elaborative processing that contributes to long-term retention and comprehension. As indicated by Robinson and Schraw (1994), the superiority of graphic organizers over linear texts may decay with time. Also, for those who are not familiar with learning from node-link visual displays such as concept maps and argument maps, graphic organizers may be confusing and difficult to read (Dansereau, Dees, & Simpson, 1994).

2.3 Need for Cognition

Beyond the potential for the design of textual-information displays to affect recall and comprehension, individual differences also influence learning outcomes. One individual difference relating to cognitive motivation is referred to as need for cognition (Cacioppo & Petty, 1982; Cacioppo et al., 1996; Cohen, 1955), which is usually measured by a self-report questionnaire initially developed by Cacioppo and Petty (1982). Rather than an intellectual ability, need for cognition is a stable dispositional variable that reflects intrinsic preference for complex thinking and influences cognitive outcomes such as recall and learning (Cacioppo et al., 1996). Amabile, Hill, Hennessey, and Tighe (1994) and Olson, Camp, and Fuller (1984) inferred that individuals with higher need for cognition would get more enjoyment in taking cognitive challenges. This inference

somewhat corresponds to the finding that need for cognition is negatively related to stress and anxiety provoked in effortful thinking (Buhr & Pryor, 1988; Cacioppo, Petty, & Kao, 1984; Olson et al., 1984). Individuals lower in need for cognition feel more anxious and stressed while coping with complex issues because they are in fear of cognitive challenges and have low self-confidence in problem solving (Heppner, Reeder, & Larson, 1983).

Cacioppo et al. (1996) reported a positive correlation between need for cognition and the cognitive effort devoted to information-processing activity. For example, individuals high in need for cognition are likely to make more effort to think about and elaborate on information; therefore, they should remember better than those low in cognition (Craik & Lockhart, 1972). Cacioppo, Petty, and Morris (1983) found that, after reading an editorial which contains a series of argumentative information, college students with high need for cognition could remember more arguments presented in the message. Cacioppo et al. (1996) concluded that students high in need for cognition are more attentive to the quality of arguments in persuasive messages (Cacioppo et al., 1983; Petty, Well, & Brock, 1976), whereas those low in need for cognition tend to avoid actively processing arguments but rely on simple cues such as the attractiveness or credibility of the message source (Petty, Cacioppo, & Goldman, 1981; Petty & Cacioppo, 1986) and the sheer number of arguments presented in the message (Petty & Cacioppo, 1986). In addition, need for cognition seems to be related to efficiency in processing conflicting information (Kardash & Scholes, 1996), generating task-relevant thoughts after reading inconsistent information (Cacioppo et al., 1996; Lassiter, Briggs, & Bowman, 1991; Verplanken, 1991) and acquiring new knowledge (Cacioppo, Petty, Kao,

& Rodriguez, 1986; Martin, Ward, Achee, & Wyer, 1993; Wolfe & Grosch, 1990).

Cacioppo et al. (1996) summarized the relation of need for cognition to other individual-difference variables. Some positive correlations have been found between need for cognition and individuals' tendency to base their judgments on empirical information (Leary, Sheppard, McNeil, Jenkins, & Barnes, 1986), seek and scrutinize relevant information for problem solving (Berzonsky & Sullivan, 1992), embrace new possibilities (Berzonsky & Sullivan, 1992), and desire for information about various aspects of the world (Inman, McAlister, & Hoyer, 1990; Sorrentino, Bobocel, Gitta, Olson, & Hewitt, 1988). In contrast, need for cognition is negatively related to individuals' preference for predictability (Petty & Jarvis, 1996; Webster & Kruglanski, 1994), structure (Neuberg & Newsome, 1993; Petty & Jarvis, 1996), order (Petty & Jarvis, 1996; Webster & Kruglanski, 1994), and casual uncertainty (Weary & Edwards, 1994). Importantly, students high but not low in need for cognition tend not to ignore, avoid or distort new information (Venkatraman, Marlino, Kardes, & Sklar, 1990).

In short, previous studies indicated that need for cognition as an intrinsic motivational construct could be regarded as an index of individuals' preference to engage in cognitively demanding tasks and their performance on dealing with argumentative or information-conflicting messages.

2.4 Logical Thinking

Logical thinking ability implies individuals' cognitive development level. Many instruments have been used by researchers to measure students' logical thinking, such as the Group Assessment of Logical Thinking (Roadrangka, Yeany, & Padilla, 1982, 1983)

and Lawson's Classroom Test of Scientific Reasoning (Lawson, 1978). The instrument employed in this study was the Test of Logical Thinking (TOLT) which was developed by Tobin and Capie (1981).

A large number of studies in science education have reported significant relationships between formal reasoning ability and students' achievement (Lawson, 1985; Nagy & Griffiths, 1982). For acquiring knowledge of science, the level of logical thinking is an important factor (Gönen, 2008). For instance, students with higher logical thinking ability perform better on understanding physics concepts (Williams & Cavallo, 1995) and biology topics (Johnson & Lawson, 1998; Sungur & Tekkaya, 2003).

In addition, logical thinking ability plays an important role in conceptual change (Kang, Scharmann, & Noh, 2004; Park & Han, 2002). Kang et al. (2004) conducted an experiment with 171 seventh-grade girls from Korea to investigate the effect of students' cognitive characteristics on the degree of cognitive conflict. They found that students with higher logical thinking ability reported more cognitive conflict after experiencing discrepant events and felt more dissatisfied with their current conceptions. However, learners with lower logical thinking ability seemed to lack the reasoning skills needed to internally evaluate inconsistent information and to identify cognitive conflict (Lawson & Thompson, 1988). Moreover, Gorsky & Finegold (1994) and Oliva (2003) indicated that students with higher logical thinking ability could rely on themselves to process conflicting information and overcome alternative conceptions.

CHAPTER 3: METHOD

3.1 Pilot Study

A pilot study was conducted with 10 participants to assess the experimental design and instruments. A few problems were discovered. For example, several participants complained that one diagram used in the screening test was ambiguous and misleading. It also was found that participants' answers to some transfer essay questions in the posttest were off-track because those questions were not expressed clearly. Besides, reading time varied from 3 to 11 minutes for different readers; therefore, it was improper to set a fixed time limit for the completion of reading. These concerns were all addressed in the main experiment. Participants in the pilot study were excluded from participating in the main experiment.

3.2 Participants

One hundred and sixty four students from Simon Fraser University volunteered to participate in the study. All interested participants were firstly invited to take a screening test which aimed to determine whether they held misconceptions about Newtonian principles of motion. Only those demonstrating misconceptions during the screening test were eligible for inclusion in the study. In this way, 44 students who were determined to not have misconceptions were paid \$3 for taking the screening test but not asked to proceed to the experimental session. However, those who were eligible to participate in the main experiment signed a consent form and were each paid \$15 upon completion of the study's activities.

A total of 120 participants, 44 males and 76 females, took part in the main experiment. Ages ranged from 18 to 47 ($M = 22.85$, $SD = 4.84$). Of the 120 participants, 105 were undergraduate students and 15 were taking graduate programs. Also, 45 of the 120 participants spoke English as their first language; of the remaining 75 participants, 33 had been studying in English-speaking countries for more than 10 years. Each participant was randomly assigned into one of three groups: a non-refutational text group, a refutational text group or a refutational map group.

3.3 Materials and Instruments

3.3.1 Learner-Paced Texts

In this study, two texts were adapted from texts used in an earlier study (Alvermann & Hynd, 1989). The refutational text (Appendix 3) explicitly pointed out the nonscientific notions of impetus theory and contrasted Newton's ideas of motion to widely held misconceptions. The non-refutational text (Appendix 2) described Newton's theories of motion but it did not mention any possible misconceptions held by students. The refutational and non-refutational texts were of similar length (611 words and 603 words, respectively), and the parts discussing Newton's scientific theories were identical in both texts. The average Flesch-Kincaid reading grade level was 8.5 which means the texts were understandable for average 8th grade students.

A learner-paced display was used to present either the refutational text or the non-refutational text. Whenever students clicked the *NEXT* button, sentence(s) of relevant meaning would appear on the screen and the animated sentence or sentence groups would be presented in blue to help students follow the animation, as shown in Figure 3.1. After

advancing through the animation, participants could review the one-page texts before the posttest. The design of text presentation aims to parallel the display of the refutational map, which will be discussed in the following section, and reduce students' cognitive load while processing the entire pieces of texts.

Figure 3.1 Excerpt of the Animated Refutational Text

True and False Ideas about the Motion of Objects


A rock moving in the vacuum of space will keep moving forever at the same speed unless some external force causes it to stop or change its speed.

Many people have wrong ideas about the motion of objects. These wrong ideas are called impetus theory. Impetus theory arose because people believe motion must have a cause. When people couldn't see a visible cause for an object to slow down or stop, they assumed there must be a force inside the object which was put there when the object was set in motion and gradually decays. This internal force was called impetus. Contrary to impetus theory, Newton proposed that a moving object comes to a stop or begins to fall because outside (or external) forces act to change the speed or direction of the object's motion. A ball rolling across the floor, for example, is slowed by friction. Friction is a force that acts in the opposite direction of the ball's motion. Therefore, it is incorrect to think that a rolling object stops or a ball falls to the ground because of the decay of internal force (impetus).

Newton believed that an object that is carried is in motion, even if it appears to be at rest in relation to the person or thing carrying it. For instance, every object inside a car is moving at the same speed as the car. When the driver is forced to step on the brakes suddenly, the people and other loose objects move forward at the same speed as the car was moving until something stops them.

According to Newton, but not impetus theory, when an object is in motion, it moves in a straight line assuming that no force is acting on it. For an object to change directions, it must be acted on by an outside force. For a ball to move in a circle, for instance, it must be acted on by an outside force such as a string. The tension in the string pulls on the ball and keeps it from moving in a straight line.

Imagine that a person is holding a stone at shoulder height while walking forward at a fast pace. What will happen when the person drops the stone? What kind of path will the stone follow as it falls? Because a carried stone does not seem to have impetus, many people say that the stone will fall straight down, striking the ground directly under the point where it was dropped. Some even believe that the falling stone will travel backward and land behind the point where it was dropped. Actually, the stone will move forward as it falls, landing a few feet ahead of the point where it was dropped. Newton explained that the carried stone has forward motion. When the stone is dropped, it continues to move forward at the same speed as the walking person because no outside force (except air resistance) is acting to change its forward direction. Of course, as the stone falls forward it also moves downward at a steadily increasing speed. The forward and downward motions result in a curved path. In the same way, a ball fired horizontally will begin to move downward in a curved path from the moment it is fired because of the constant force of the earth's gravity. *This fact is not consistent with impetus theory, which says the ball will only move downward after its horizontal force is used up.*



3.3.2 Learner-Paced Refutational Map

The refutational map (Appendix 4) used in this study was a type of argument map in the form of a box-and-arrow diagram with boxes corresponding to ideas and arrows corresponding to the logical (or evidentiary) relationships in the refutational text, as shown in Figure 3.2. The refutational map was transformed from the refutational text and represented all the true and false conceptions about the motion of objects that were discussed in the refutational text. In the refutational map, propositions concerning

theories, misconceptions, explanations and examples appeared as sentences in 16 rounded rectangular boxes. The directionality of logical relations between boxes was indicated by an arrowhead and the arrows were marked with + or – signs to imply whether the relations were supportive (+) or unsupportive (–).

According to the Gestalt grouping principle of proximity and similarity, related propositions should be placed close to one another, and a consistent color system should be applied to help readers differentiate between true and false concepts (Dwyer et al., 2010). Therefore, in this refutational map, correct ideas were presented in green boxes and spatially grouped together, in contrast to those incorrect ideas presented in grey boxes.

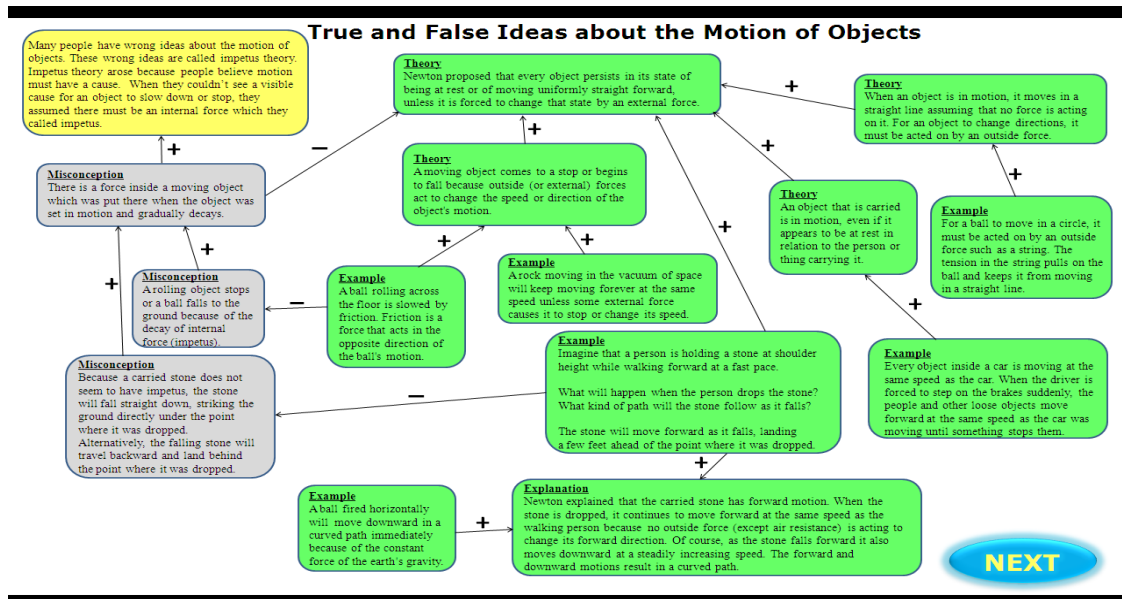
In previous studies, researchers found that the complexity of map displays could cause confusion or “map shock” which may result in lack of patience to further process information in the map or may deter learners from effective learning (Dansereau et al., 1994). Therefore, the display of the refutational map was designed as a learner-controlled animation which started with the description of meta-claim that was exceptionally presented in a yellow box. And each box would appear on the screen in predefined sequence when readers clicked the *NEXT* button. Finally, participants could review the one-page map as a whole after going through the animation.

3.3.3 Demographic Questionnaire

A questionnaire (Appendix 1) was used to collect background information about age, sex, highest level of education attained, first language and years of studying in English-speaking schools if English was not their first language.

Figure 3.2

Excerpt of the Refutational Map



3.3.4 Need for Cognition

Each participant completed the 18-item Need for Cognition self-report instrument (short form) that was intended to assess individuals' tendency to engage in and enjoy intellectual activities involving complex thinking. Participants used a scale from 1 (*strongly disagree*) to 5 (*strongly agree*) to rate the extent to which they agreed with items such as "I would prefer complex to simple problems." and "Thinking is not my idea of fun." The internal consistency reliability of this instrument was reported to be high ($\alpha = .90$) in previous studies (Cacioppo et al., 1984). Furthermore, Sadowski and Gulgoz (1992) reported a test-retest correlation ($r = .88$) over a 7-week period with a sample of 71 undergraduates, which indicated that need for cognition is a stable individual difference variable.

A series of studies investigating the relationship between need for cognition and other individual-difference variables suggested the convergent and discriminant validity of the scale (Cacioppo et al., 1996). Specifically, need for cognition scores were not influenced by sex (Sadowski, 1993; Spotts, 1994; Tolentino, Curry, & Leak, 1990), or by potential response biases such as test anxiety (Cacioppo & Petty, 1982) and social desirability (Cacioppo & Petty, 1982; Fletcher, Danilovics, Fernandez, Peterson, & Reeder, 1986; Olson et al., 1984; Petty & Jarvis, 1996).

3.3.5 Test of Logical Thinking

The Test of Logical Thinking (TOLT) developed by Tobin and Capie (1981) was administered. The test consists of 10 two-tier items designed to measure controlling variables (items 1 and 2), proportional (items 3 and 4), probabilistic (items 5 and 6), correlations (items 7 and 8) and combinational reasoning (items 9 and 10). For the first 8 items, participants were required to select the best answer from five possibilities, and then chose one of the five justifications to support their choice. Only when participants gave both a correct choice of possibilities and a correct reason could they get 1 point for the item; or the score of the item would be marked as zero. Tobin and Capie (1981) suggested TOLT is a valid measure of formal reasoning ability, which claim can be supported by the high internal consistency reliability ($\alpha = .85$) and the correlation coefficient of .80 with Piaget's clinic interview method.

3.3.6 Screening Test

There were two questions in the screening test to help determine which of the

original participants held misconceptions about Newtonian principles of motion. For each question, participants were asked to choose a path (A, B, C or D) an object would follow under certain circumstance, and then use a scale ranging from *complete guess* to *complete confidence* to rate the extent to which they were confident in their choice. The self-reported confidence level functioned as a double check to diagnose whether the choice gave a true picture of their understanding. For example, participants showing low confidence in their answers were regarded to have misconceptions, even though they had chosen the correct path. Therefore, those who not only correctly responded to the two questions but also revealed high confidence in their answer to each question were excluded from the study.

3.3.7 Outcome Tests

There were three tests for participants to take after studying the assigned materials: a free recall test, a transfer essay test and a transfer multiple-choice test. The free recall test (Appendix 5) asked participants to write everything they could remember from the materials they studied. They were encouraged to write in complete sentences but not to worry about spelling and grammar. The free recall test was designed to examine the effects of treatment-specific readings on retention.

Participants then did five transfer essay questions (Appendix 6). Three questions were adapted from those used in an earlier study (Hynd & Alvermann, 1989) and two questions were written by me. The questions that required participants to predict and explain various phenomena using what they learned from the reading materials aimed to

explore the effects of treatment readings on transfer understanding. Each transfer essay question was divided into two subquestions with the purpose of guiding participants to provide pertinent rather than excursive responses which, importantly, could better reflect their conceptual change.

The transfer multiple-choice test consisted of 9 questions (Appendix 7), which were drawn from the 30-item Force Concept Inventory, an instrument widely used by researchers to assess participants' overall grasp of Newtonian theories (Hestenes, Wells, & Swackhamer, 1992). Each question offered 5 options but only had one correct answer, with the other four options corresponding to commonly held misconceptions.

3.4 Procedure

All interested students took the screening test and only those who evidenced misconceptions and/or revealed little confidence in their answers were retained for the study. However, students who correctly responded to the two questions and correspondingly showed higher confidence were told that they were not eligible for the next session of the experiment but not informed of any reason for their exclusion allowing for the reliability of the screening test. Every eligible participant was provided with an ID number to be used for data gathering and analysis.

Prior to the treatment session, the demographic questionnaire, the 18-item Need for Cognition Scale and the Test of Logical Thinking were completed consecutively. After being randomly assigned into treatment groups, participants firstly read a one-page instruction which showed how to advance through the animated presentation and also emphasized the necessity to work through the reading materials, especially the

relationships among concepts, attentively because they would later be tested without access to the readings. For participants in the refutational map group, one more page was provided to train them how to study with the refutational map. Participants were allowed to work at their own pace, although they were told that 8 minutes would usually be enough time. They were provided with a clock and asked to write down the time before and after studying on the answer sheet.

After reading the treatment-specific materials, participants were invited to do a Sudoku Puzzle to reduce the effect of short-term memory. Three minutes later, they were asked to write down everything they could remember from the reading materials they studied before doing the Sudoku Puzzle. They were encouraged to write in complete sentences but not to worry about spelling and grammar. After the free recall test, participants completed the transfer essay test and the transfer multiple-choice test. Overall, it took approximately 75 minutes for a participant to go through the whole procedure.

CHAPTER 4: RESULTS

4.1 Overview of the Types of Data Collected

This study collected the following types of data: (1) demographic data including age, sex, education level, first language and English capability; (2) scores on the need for cognition scale which indicate participants' attraction to complex cognitive thinking; (3) scores on the test of logical thinking that reflect individuals' reasoning abilities in physics; (4) time spent on texts or map reading; (5) scores on the free recall test which help explore the effects of treatment-specific reading materials on retention; (6) scores on the transfer essay-type questions and (7) transfer multiple-choice questions that both reveal the effects of treatment readings on participants' understanding.

4.2 Scoring the Free Recall Test

A propositional scoring method was used to score the free recall test (Chmielewski & Dansereau, 1998; Holley, Dansereau, McDonald, Garland, & Collins, 1979). The texts were subdivided into a set of idea units, each containing a single piece of information. Both the refutational text and the refutational map were composed of 56 key propositions, and the non-refutational text was decomposed into 47 propositions. Specifically, all of the three treatment-specific reading materials included 40 identical propositions discussing Newtonian theories about the motion of objects. The additional 7 propositions in the non-refutational text were general introductory descriptions such as “we learn from experience” and “we get ideas about motion of objects from our daily lives”. The remaining 16 propositions in the refutational text or map were segments refuting

commonly held misconceptions, such as “many people have wrong ideas about the motion of objects” and “impetus theory arose because people believe motion must have a cause”.

A scorer unaware of treatment conditions coded the free recall responses by comparing the participants’ recalls with the propositions listed in the scoring protocol. The propositions that were completely and accurately presented were assigned 1. Those partially stated or partially accurate were assigned 0.5. If a participant only recalled key words instead of sentences, such as gravity, friction or impetus, each key word was assigned 0.25. Statements that were totally inaccurate or irrelevant to the reading materials were assigned 0. The overall free recall score for each participant was calculated by summing the scores for each statement. Scoring reliabilities were established by having a second rater score 20 randomly selected samples of the free recall, $r = .92$.

4.3 Scoring Transfer Essays

A template of model answers and a scoring rubric were developed to code the five transfer essay-type questions, each of which was constituted by two sub-questions. As a whole, each transfer essay question was scored 0-4 according to the degree of correctness and completeness compared with the model answers.

To make the scoring process more convenient and precise, the model answer to each question was divided into key points which were assigned different weights (or scores) based on their relevance and importance. Furthermore, to include and properly classify all the relevant responses, a scorer blind to treatment conditions first scanned the participants’

answers before grading to incorporate unanticipated cases into the rubric, as shown in Table 4.1. The score for each of the five questions for individual participant was determined by matching the answer with the rubric and summing the credits for each point.

Table 4.1 Excerpt of the Scoring Rubric

Question	
A car traveling at 100 kilometers per hour (kph) drives off a cliff, as shown in the diagram below. (1) Ignoring the resistance of air, describe the most possible path that the car would take; (2) Write the explanation of the reasoning behind your answer.	
Scores	Points
2	Path: the car will move downward in a curved path after it falls off the cliff.
0	If the answer reflects one of the misconceptions, including: (1) The car will move horizontally first for some time and then fall straight down after its horizontal force is used up. (2) The car will move horizontally for some time and then move downward in a curved path while its horizontal force is decaying and finally fall straight down after the horizontal force is used up. (3) The car will fall straight down, striking the ground directly under the point where it fell off the cliff.
2	For the explanation: inertia (forward motion) and gravity (downward motion) work together to make the car move downward in a curved path.
1	If the explanation only includes: the car keeps moving forward because of inertia.
1	If the explanation only includes: gravity makes the car fall straight down.
0.5	If the explanation includes the following three parts: inertia + gravity + misconceptions (impetus theory or internal force)
0.25	If the explanation includes the following two parts: inertia or gravity + misconceptions (impetus theory or internal force)
0	If the explanation only includes misconceptions, such as, the car falls because the internal force is decaying or used up.

All the answers to a given question were scored before proceeding to the next one to insure consistent standards in scoring. The overall transfer essay score for an individual participant was calculated by summing the scores for each question. A second scorer using the same rubric graded 20 samples of transfer essays, $r = .90$.

4.4 Analysis and Results

4.4.1 Outliers and Normality

Every outcome variable in each of the three groups was checked for normality and outliers prior to doing data analysis. Two obvious outliers were detected from the non-refutational text reading group. One was found in free recall scores ($z = 4.24$). The original score was therefore adjusted from 35.25 to 20.25, which was one measurement unit higher than the next highest score ($z = 2.30$), to reduce the impact of the outlier on the outcome of the statistical analysis (Tabachnick & Fidell, 2007). Similarly, a minor adjustment was made to the other outlier found in the transfer multiple-choice scores ($z = 3.42$) which was lowered from 9 to 8.

Several checks of normality and outliers were conducted to gain a thorough understanding of the shape of the distribution of each variable in three study groups after dealing with the two outliers. Table 4.2 shows that the skewness and kurtosis values are all less than or close to ± 1 , indicating that distributions of these variables are within the limits of a normal distribution. In addition, standardized values, which were produced by dividing the values for skewness or kurtosis by their standard errors, confirm that most of the variables are normally distributed with standardized values both for skewness and kurtosis roughly between ± 1.96 . However, the transfer multiple-choice scores in the non-refutational text reading group and those in the refutational map reading group could be judged as deviating from normality with the standardized values for skewness of 2.54 and 2.14 respectively. Similarly, the skewness of the free recall scores in the non-refutational text reading group had a standardized value of 2.05. The Shapiro-Wilk test serves as another way to examine the shape of the distributions. As shown in Table

4.2, 4 of the 15 variables failed the test of normality at the $p < .01$ level. However, I judged that none of the potential departures from normality were extreme and that it was reasonable to analyse all variables with parametric statistics.

Table 4.2 **Test of Normality**

		Skewness/SE		Kurtosis/SE		Shapiro-Wilk
Group		Skewness (SE)	(critical value)	Kurtosis (SE)	(critical value)	
NFC	NRT	-.28(.37)	-.76	-.51(.73)	-.70	.559
	RT	-.20(.37)	-.54	-.75(.73)	-1.03	.253
	RM	-.70(.37)	-1.89	.06(.73)	.08	.048
TOLT	NRT	-.32(.37)	-.86	-.98(.73)	-1.34	.035
	RT	-.60(.37)	-1.62	-.66(.73)	-.90	.006
	RM	-.74(.37)	-2.00	-.27(.73)	-.37	.003
Transfer Essay	NRT	-.11(.37)	-.30	-.51(.73)	-.70	.341
	RT	-.29(.37)	-.78	-.59(.73)	-.81	.448
	RM	-.10(.37)	-.27	-.45(.73)	-.62	.855
Transfer MC	NRT	.94(.37)	2.54	1.16(.73)	1.59	.005
	RT	.12(.37)	.32	.49(.73)	.67	.173
	RM	.79(.37)	2.14	-.27(.73)	-.37	.003
Free Recall	NRT	.76(.37)	2.05	-.03(.73)	-.04	.038
	RT	.29(.37)	.78	-.96(.73)	-1.32	.111
	RM	.07(.37)	.19	-.27(.73)	-.37	.804

4.4.2 Test of Equivalence

Table 4.3 summarizes the distribution of sex and participants' English capability across the three groups. It also presents the means and standard deviations (in parentheses) for age, need for cognition, the test of logical thinking and time used to go through the animated reading materials. A one-way MANOVA revealed that no difference across three treatment groups was detected, Wilks' Lambda = .93, $F(8, 228) = 1.14$, $p = .34$, $\eta_p^2 = .04$. Follow-up ANOVAs showed that no statistically significant difference was found among three groups in age, $F(2, 117) = .47$, $p = .63$, reading time, $F(2, 117) =$

2.08, $p = .13$, need for cognition, $F(2, 117) = .46$, $p = .63$, and test of logical thinking, $F(2, 117) = 1.15$, $p = .32$.

Table 4.3 Demographic Data, Need for Cognition, Logical Thinking and Reading Time

Group	Female	English Capability*	Age	Need for Cognition	Logical Thinking	Reading Time (min)
Non-Refutational Text Group	67.50%	60%	23.30 (6.01)	59.53 (11.50)	5.30 (2.62)	4.58 (2.34)
Refutational Text Group	62.50%	65%	22.98 (4.63)	61.80 (10.20)	5.90 (2.56)	4.75 (1.96)
Refutational Map Group	60.00%	70%	22.28 (3.65)	60.20 (10.83)	6.13 (2.35)	5.43 (1.52)
Total	63.00%	65%	22.85 (4.84)	60.51 (10.81)	5.78 (2.52)	4.92 (1.99)

* Studying in English-speaking countries for more than 10 years

4.4.3 Correlations

Table 4.4 shows the Pearson correlations among all the continuous variables. The correlation between logical thinking and the outcome tests was consistently stronger than that between need for cognition and the outcome tests.

Table 4.4 Correlations

	NFC	TOLT	Essay	MC	Free Recall
NFC	-	.36**	.22*	.15	.30**
TOLT		-	.45**	.25**	.47**
Essay			-	.51**	.58**
MC				-	.29**
Free Recall					-

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

4.4.4 The Analyses of Outcome Tests

A two-factor MANOVA was conducted to investigate a potential interaction between

experimental treatments and logical thinking on the overall outcome measures which included free recall, transfer essay and multiple choice scores as three dependent variables. Students in each of the three treatment groups were divided into two subgroups (median-split) according to their scores on the Test of Logical Thinking, ranging from 0 to 9. The scores less than or equal to 6 were categorized as lower logical thinking ability, and those greater than 6 represented higher logical thinking ability. Table 4.5 shows the means and standard deviations for the free recall, transfer essay and multiple choice tests separately for the three text reading groups and the two subgroups higher or lower in logical thinking. No serious violation was detected in the test of preliminary assumptions.

Table 4.5 Descriptive Statistics

	Group	TOLT	Mean	SD	N
Free Recall	NRT	Low	5.43	4.10	25
		High	10.53	5.30	15
	RT	Low	6.23	3.89	20
		High	11.41	4.92	20
	RM	Low	11.25	5.24	20
		High	13.41	4.17	20
Essay	NRT	Low	7.00	4.13	25
		High	10.90	3.09	15
	RT	Low	7.83	3.94	20
		High	12.25	2.89	20
	RM	Low	10.93	4.55	20
		High	11.23	3.34	20
MC	NRT	Low	2.48	1.36	25
		High	3.67	2.00	15
	RT	Low	3.65	2.13	20
		High	3.80	1.74	20
	RM	Low	3.10	2.65	20
		High	3.70	2.49	20

A 2×3 MANOVA was conducted with treatment conditions and logical thinking

ability as the two factors. The interaction term produced Wilks' Lambda = .91, $F(6, 224) = 1.91$, $p = .08$, $\eta_p^2 = .05$. I judged that the estimated probability of type I error was close enough to the conventional and arbitrary threshold of $p = .05$ that an interaction was statistically detected. Both treatment conditions (Wilks' Lambda = .83, $F(6, 224) = 3.78$, $p = .001$, $\eta_p^2 = .09$) and readers' level of logical thinking (Wilks' Lambda = .80, $F(3, 112) = 9.57$, $p < .001$, $\eta_p^2 = .20$) showed statistically significant main effects.

4.4.4.1 Free Recall Test

A follow-up 2×3 ANOVA test revealed the impact of treatment conditions and logical thinking on the free recall test. The Levene test of homogeneity reported that no difference in the variances across the groups was detected ($p = .47$). According to the ANOVA test, the interaction effect between treatments and logical thinking was not statistically significant, $F(2, 114) = 1.40$, $p = .25$. The treatment readings exerted significant effect on the free recall scores, $F(2, 114) = 9.95$, $p < .001$, $\eta_p^2 = .15$. Post hoc comparisons using the Tukey HSD test showed that participants in the non-refutational reading group ($M = 7.34$, $SD = 5.17$) did almost as well as those in the refutational text reading group ($M = 8.82$, $SD = 5.11$). But the refutational map studying group ($M = 12.33$, $SD = 4.80$) significantly outperformed the other two groups in the free recall test.

In addition, there was a statistically significant effect of logical thinking on the free recall achievement, $F(1, 114) = 24.06$, $p < .001$, $\eta_p^2 = .17$. Participants with higher logical thinking ability ($M = 11.90$, $SD = 4.83$) did much better in the free recall test than those with lower logical thinking ability ($M = 7.47$, $SD = 5.05$).

4.4.4.2 Transfer Essay Test

In this study, transfer essay scores functioned as an indicator of participants' transfer comprehension. Cronbach's alpha for the 5 items ($\alpha = .71$) was satisfactory. The Levene test of homogeneity detected no difference in the variances across the groups ($p = .17$). A 2×3 ANOVA test indicated that the interaction between treatment readings and logical thinking was significant, $F(2, 114) = 3.57, p = .03, \eta_p^2 = .06$.

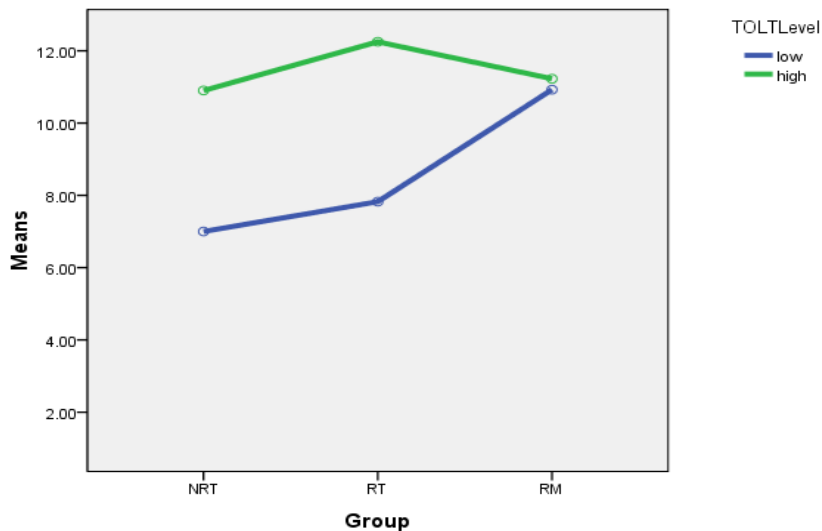
What's more, the difference among the three treatment groups on the transfer essay scores was statistically significant, $F(2, 114) = 3.11, p = .05, \eta_p^2 = .05$. A post hoc Tukey HSD test revealed that the participants studying the refutational map ($M = 11.08, SD = 3.94$) performed significantly better on the transfer essay test than those studying the non-refutational text ($M = 8.46, SD = 4.19$). The performance of the refutational text study group ($M = 10.04, SD = 4.08$) was not statistically different from that of the other two groups in the transfer essay test.

Logical thinking was also significantly related to the transfer essay scores, $F(1, 114) = 17.27, p < .001, \eta_p^2 = .13$. Students with higher logical thinking ability ($M = 11.51, SD = 3.11$) performed better than those demonstrating lower logical thinking ability ($M = 8.46, SD = 4.47$).

Since the analyses above indicated an interaction between treatments and logical thinking ability on the essay performance, a series of one-way ANOVAs were conducted here to further explore whether the factor of logical thinking influenced the cognitive effects of refutational maps; more specifically, how the interaction played out for the lower and higher level logical thinkers.

It was found that participants with higher logical thinking ability performed equally well on the essay questions across the three reading groups, $F(2, 52) = .94, p = .40$. However, for those demonstrating lower logical thinking ability, treatment-specific readings contributed to a statistically significant difference in the transfer essay scores, $F(2, 62) = 5.17, p = .008, \eta_p^2 = .14$. Post hoc comparisons using the Tukey HSD test indicated that the refutational map helped participants with lower logical thinking ability achieve significantly better scores ($M = 10.93, SD = 4.55$) in the transfer essay test than non-refutational text ($M = 7.00, SD = 4.13$) and refutational text ($M = 7.83, SD = 3.94$) did. Figure 4.2 shows that, in non-refutational and refutational text groups, the factor of logical thinking exerted large impact on participants' performance on the transfer essay questions, Cohen's $d = 1.07$ and 1.28 , respectively. But studying the refutational map almost eliminated the effect of logical thinking on the transfer essay test (Cohen's $d = .08$).

Figure 4.1 Transfer Essays: Comparison of Means between Low and High Logical Thinkers



4.4.4.3 Transfer Multiple-Choice Test

In addition to transfer essay scores, participants' performance on the multiple-choice test also reflected their transfer understanding on Newton's laws of motion after reading the treatment-specific materials. There were 9 multiple-choice questions, which yielded a low Cronbach's alpha value ($\alpha = .68$). Each of the questions was assigned 1 for correct answers and 0 for incorrect answers. Accordingly, the total score of the multiple-choice test for individual participant ranged from 0 to 9. The Levene test of homogeneity suggested that no difference in the variances across the groups was detected ($p = .10$). A 2×3 ANOVA test found that neither treatment conditions, $F(2, 114) = .95, p = .39$, nor logical thinking, $F(1, 114) = 2.83, p = .10$, had significant effect on the multiple-choice test. Also, there was no interaction between treatment readings and participants' level of logical thinking, $F(2, 114) = .60, p = .55$.

CHAPTER 5: DISCUSSION

5.1 Discussion of the Results

The results of this study indicate that the refutational map is a useful cognitive tool to strengthen recall and foster conceptual change. It was found that studying a refutational map facilitated free recall and knowledge transfer. On the free recall test, participants studying the refutational map significantly outperformed those studying either non-refutational or refutational texts. The result is in line with the conclusions of previous studies that reported graphic displays as an effective diagrammatic technique for presenting textual information (Dwyer et al., 2010; Novak & Gowin, 1984; Nesbit & Adesope, 2006; Zeitz & Anderson-Inman, 1992). In particular, as discussed in the literature, spatial representations allow easier information retrieval (Larkin & Simon, 1987; Oliver, 2009) and lower cognitive burden (O'Donnell, 1994; Tzeng, 2010; Vekiri, 2002). Therefore, it could be deduced that refutational maps may serve as an effective format to help readers understand and encode key points in study materials.

In addition, the results indicated that studying the refutational map had a positive impact on participants' knowledge transfer. It was shown that participants studying the refutational map achieved the highest scores among the three groups in the transfer essay test, though only the difference in scores between the refutational map group and the non-refutational text group was statistically significant. These findings suggest that refutational maps, which not only present common misconceptions but also visualize the embedded logical relations among concepts, could optimize the features of refutational texts and graphic organizers to efficiently engage learners in cognitive information processing and promote cognitive conflict for logical reasoning and conceptual change.

On the multiple-choice test, differences in the mean scores of the three treatment groups were not statistically detected. This inconclusive result may be due to the low internal consistency ($\alpha = .68$) of the 9-item multiple-choice test. Another possible explanation is that the multiple-choice test format per se may not allow a sensitive measure of conceptual change. Therefore, the multiple-choice test scores cannot be used to further support the superior effectiveness of the refutational map on students' knowledge transfer.

The least expected finding in this study was that differences between the refutational and non-refutational text groups were not statistically detected in any of the free recall, the transfer essay and the multiple-choice tests. This result contradicts the findings of other studies which found that studying refutational text was more effective in promoting conceptual change than studying non-refutational text (Ariasi & Mason, 2010; Diakidoy et al., 2003; Guzzetti et al., 1993; Guzzetti, 2000; Hynd & Alvermann, 1986; Hynd, 2001; Palmer, 2003).

As an index of cognitive development level, logical thinking ability was indicated in earlier studies to have significant relation to acquisition of science concepts (Gönen, 2008; Johnson & Lawson, 1998; Sungur & Tekkaya, 2003; Williams & Cavallo, 1995). Logical thinking ability was associated with efficiency in processing inconsistent information and initiating cognitive conflict for conceptual change (Gorsky & Finegold, 1994; Kang et al., 2004; Lawson & Thompson, 1988; Oliva, 2003; Park & Han, 2002). Similar to the findings of previous research, the results of this study revealed that participants with higher level of logical thinking ability significantly outperformed those with lower level of logical thinking ability in both the free recall and the transfer essay

tests. However, participants lower and higher in logical thinking ability did not perform differently on the multiple-choice questions. Furthermore, it was found that the refutational map moderated the effect of logical thinking on transfer essay scores. To put it another way, learners with lower logical thinking ability benefited more from studying refutational maps as measured by the transfer essay test.

In previous studies, need for cognition, as an intrinsic motivational construct indicating individuals' attraction to cognitively demanding challenges (Cacioppo & Petty, 1982; Cacioppo et al., 1996), was reported to be positively correlated with processing argumentative information (Craik & Lockhart, 1972; Cacioppo et al.1983; Kardash & Scholes, 1996; Lassiter & et al., 1991; Verplanken, 1991). The findings of this study, which were congruent with those of earlier research, revealed a positive correlation between need for cognition and scores of the outcome tests including the free recall, the transfer essay and the multiple-choice tests.

5.2 Implications

As a time- and cost-effective intervention, the application of refutational maps holds promise for wide and flexible adoption in classroom settings. This study has shed light on the effectiveness of refutational maps for teaching and learning science. In classroom settings, pre-constructed refutational maps, which are used in the same way as traditional text materials, can be easily integrated into common classroom learning activities.

Refutational maps can also be used as an adjunct to traditional reading materials to facilitate teaching and learning. For example, teachers would think of providing students with refutational maps to aid them to preview and/or review their readings after class for

higher learning efficiency. Also, teachers can ask students to construct refutational maps individually or collaboratively during the class. The exercise of refutational mapping may not only guide students to actively engage in class activities, but may also help readers think more deeply on the embedded relations between concepts presented in the reading materials.

Refutational maps are more helpful for students with lower logical thinking ability. Therefore, taking students' unequal logical thinking abilities into account, teachers should employ refutational maps to narrow the gap between lower and higher logical thinkers and therefore support mutual improvement.

5.3 Limitations and Future Work

In this study, a multiple-choice test was one of the measures used to assess students' transfer understanding. However, neither treatment readings nor logical thinking ability were found to influence students' transfer multiple-choice scores. The failure to detect any difference across groups may be attributed to the test's low internal consistency reliability. The test should only be used in future studies if it is modified to improve its psychometric characteristics.

Students traditionally learn disciplinary knowledge from texts, so probably many participants in this study were not familiar with learning node-link graphic representations. Those who for the first time learned such visual displays as refutational maps may have felt confused about how to process the map and then lose their motivation to keep learning attentively. Therefore, training might be helpful because the degree of familiarity with studying refutational maps may influence participants' learning

outcomes.

This study only examined the relationship of logical thinking ability and need for cognition on learning with refutational maps and did not investigate the roles of other individual characteristics, such as spatial and/or verbal reasoning ability, which may be related to the efficiency of map information processing. It may be that students with higher spatial and/or verbal reasoning ability would more efficiently learn from refutational maps and achieve better scores on the outcome tests.

In addition, this study compared students' performance only in an immediate post-test and found that reading refutational maps was a relatively effective strategy for promoting conceptual change. However, according to Robinson & Schraw (1994), the effectiveness of graphic organizers over linear texts attenuates with time. Therefore, future studies could explore whether the superiority of refutational maps over non-refutational and refutational texts is sustained on delayed post-tests.

Furthermore, the findings of this study, unlike those of previous research, did not indicate that refutational text was more effective than non-refutational text for promoting students' conceptual change. That may be because the texts used in this study were too short and understandable to challenge students' memory and comprehension. It should be considered that whether the results would be different if the reading materials used in this study were longer and more complicated.

Finally, refutational maps have been found in this study to be useful for promoting conceptual change in physics. Further research would be necessary to investigate whether refutational maps could be applied in other subject areas in addition to science disciplines. Also, it is worth probing the most effective and efficient means of using refutational

maps. For example, future studies could compare the effects of studying pre-constructed refutational maps and refutational mapping, either individually or collaboratively.

Besides, in this study, the refutational map was designed as a learner-paced animation. It would be useful to explore whether one-page static refutational maps could be as effective as animated ones, and then develop the most time- and cost-effective ways to integrate refutational maps into classroom learning activities.

REFERENCE LIST

- Akgün, Ö. E., & Deryakulu, D. (2007). The effects of refutational text and predict-observe-explain strategies on students' levels of cognitive conflict and conceptual change. *Ankara University, Journal of Faculty of Educational Sciences*, 40 (1), 17-40.
- Al-Issa, A. (2006). Schema theory and L2 reading comprehension: Implications for teaching. *Journal of College Teaching & Learning*, 3(7), 41-48.
- Alvermann, D. E. (1981). The compensatory effect of graphic organizers on descriptive texts. *Journal of Educational Research*, 75, 44-48.
- Alvermann, D. E., & Hague, S.A. (1989). Comprehension of counterintuitive science text: Effects of prior knowledge and text structure. *Journal of Educational Research*, 82, 197-202.
- Alvermann, D. E., & Hynd, C. R. (1989). Effects of prior knowledge activation modes and text structure on nonscience majors' comprehension of physics. *Journal of Educational Research*, 83 (2), 97-102.
- Amabile, T. M., Hill, K. G., Hennessey, B. A., & Tighe, E. M. (1994). The work preference inventory: Assessing intrinsic and extrinsic motivational orientations. *Journal of Personality and Social Psychology*, 66, 950-967.
- Anderson, R. C., Spiro, R. J., & Anderson, M. C. (1978). Schemata as scaffolding for the representation of information in connected discourse. *American Educational Research Journal*, 15 (3), 433-440.
- Anderson, O. R., & Botticelli, S. (1990). Quantitative analysis content organization in some biology texts varying in textual composition. *Science Education*, 74, 167-182.
- Ariasi, N., & Mason, L. (2010). Uncovering the effect of text structure in learning from a science text: An eye-tracking study. *Instructional Science*. DOI 10.1007/s11251-010-9142-5
- Arnaudin, M. W., & Mintzes, J. J. (1985). Students' alternative conceptions of the human circulatory system: A cross age study. *Science Education*, 69 (5), 721-733.
- Ausubel, D. P. (1960). The use of advanced organizers in the learning and retention of meaningful verbal behavior. *Journal of Educational Psychology*, 51, 267-272.
- Ausubel, D. P. (1963). *The psychology of meaningful verbal learning*. New York: Grune & Stratton.

- Ausubel, D. P. (1968). *Educational psychology: A cognitive approach*. New York: Holt, Rinehart & Winston.
- Bahrlick, H. P. (1979). Maintenance of knowledge: Questions about memory we forgot to ask. *Journal of Experimental Psychology*, *108* (3), 296-308.
- Bartlett, F. C. (1932). *Remembering*. Cambridge: Cambridge University Press.
- Ben-David, R. (2002). Enhancing comprehension through graphic organizers. Retrieved from Eric, No. ED461907.
- Berzonsky, M. D., & Sullivan, C. (1992). Social-cognitive aspects of identity style: Need for cognition, experimental openness, and introspection. *Journal of Adolescent Research*, *7*, 140-155.
- Birdsell, D. S., & Groarke, L. (2007). Outlines of a theory of visual argument. *Argumentation and Advocacy*, *43*, 103-113.
- Brooks, L., Dansereau, D., Spurlin, J., & Holley, C. (1983). Effects of headings on text processing. *Journal of Educational Psychology*, *75*(2), 292-302. doi:10.1037/0022-0663.75.2.292.
- Buhr, T. A., & Pryor, B. (1988). Receiver's apprehension and need for cognition. *Psychological Reports*, *62*, 995-996.
- Bulunuz, N. (2007). Understanding of earth and space science concepts: Strategies for concept building in elementary teacher preparation. *Early Childhood Education Dissertations*, http://digitalarchive.gsu.edu/ece_diss/2.
- Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology*, *42*, 116-131.
- Cacioppo, J. T., Petty, R. E., & Morris, K. J. (1983). Effects of need for cognition on message evaluation, recall, and persuasion. *Journal of Personality and Social Psychology*, *45*, 805-818.
- Cacioppo, J. T., Petty, R. E., & Kao, C. F. (1984). The efficient assessment of need for cognition. *Journal of Personality Assessment*, *48*, 306-307.
- Cacioppo, J. T., Petty, R. E., & Kao, C. F., & Rodriguez, R. (1986). Central and peripheral routes to persuasion: An individual difference perspective. *Journal of Personality and Social Psychology*, *51*, 1032-1043.
- Cacioppo, J. T., Petty, R. E., Feinstein, J. A., & Jarvis, W. B. (1996). Dispositional differences in cognitive motivation: The life and times of individuals varying in need for cognition. *Psychological Bulletin*, *119*, 197-253.

- Carlsen, D. D., & Andre, T. (1992). Use of a microcomputer simulation and conceptual change text to overcome student preconceptions about electric circuits. *Journal of Computer-Based Instruction*, 19 (4), 105-109.
- Chambers, S. K., & Andre, T. (1997). Gender, prior knowledge, interest and experience in electricity and conceptual change text manipulation in learning about direct current. *Journal of Research in Science Teaching*, 34(2), 107-123.
- Chan, C., Burtis, J., & Bereiter, C. (1997). Knowledge building as a mediator of conflict in conceptual change. *Cognition and Instruction*, 15 (1), 1-40.
- Chmielewski, T. C., & Dansereau, D. F. (1998). Enhancing the recall of text: Knowledge mapping training promotes implicit transfer. *Journal of Educational Psychology*, 90, 407-413.
- Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behaviour*, 11, 671-684.
- Dansereau, D. F., Dees, S. M. & Simpson, D. D. (1994). Cognitive Modularity: Implications for Counseling and representation of personal issues. *The Journal of Counseling Psychology*, 41, 513-523.
- Dee-Lucas, D., & Larkin, J. H. (1995). Learning from electronic texts: Effects of interactive overviews for information access. *Cognition and Instruction*, 13, 431-468.
- Diakidoy, I. N., Kendeou, P., & Ioannides, C. (2003). Reading about energy: The effects of text structure in science learning and conceptual change. *Contemporary Educational Psychology*, 28, 335-356
- Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education*, 5, 61-84.
- Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education* 25, 671-688.
- Dwyer, C., Hogan, M., & Stewart, I. (2010). The evaluation of argument mapping as a learning tool: Comparing the effects of map reading versus text reading on comprehension and recall of arguments. *Thinking Skills and Creativity*, 5 (1), 16-22.
- Dykstra, D. I., Boyle, C. F., & Monarch, I. A. (1992). Studying conceptual change in learning physics, *Science Education*, 76, 615-652.

- Fisher, K.M. (1985). A misconception in biology: amino acids and translation. *Journal of Research in Science Teaching*, 22 (1), 53-62.
- Fletcher, F. J. O., Danilovics, P., Fernandez, G., Peterson, D., & Reeder, G. D. (1986). Attributional complexity: An individual difference measure. *Journal of Personality and Social Psychology*, 51, 875-884.
- Fontanini, I. (2004). Reading theories and some implications for the processing of linear texts and hypertexts. *Linguagem & Ensino*, 7(2), 165-184.
- Gönen, S. (2008). A study on student teachers' misconceptions and scientifically acceptable conceptions about mass and gravity. *Journal of Science Education and Technology*, 17 (1), 70-81.
- Gorsky, P., & Finegold, M. (1994). The role of anomaly and of cognitive dissonance in restructuring students' concepts of force. *Instructional Science*, 22, 75-90.
- Griffin, C., & Tulbert, B. (1995). The effect of graphic organizers on students' comprehension and recall of expository texts: A review of the research and implications for practice. *Reading and Writing Quarterly*, 11(1), 73-89.
- Guzzetti, B.J., Snyder, T.E., Glass, G.V., & Gamas, W.S. (1993) Promoting conceptual change in science: A comparative meta-analysis of instructional interventions from reading education and science education. *Reading Research Quarterly*, 28, 117-155.
- Guzzetti, B. J. (2000). Learning counter-intuitive science concepts: what have we learned from over a decade of research? *Reading and Writing Quarterly* 16: 89-98.
- Hepner, P. P., Reeder, B. L., & Larson, L. M. (1983). Cognitive variables associated with personal problem-solving. *Journal of Counseling Psychology*, 30, 537-545.
- Hestenes, D., Wells, M., & Swackhammer, G. (1992). Force concept inventory. *Physics Teacher*, 30, 141-158.
- Hofman, R., & Oostendorp, H. V. (1999). Cognitive effects of a structural overview in a hypertext. *British Journal of Educational Technology*, 30(2), 129-140.
- Holley, C. D., Dansereau, D. F., McDonald, B. A., Garland, G. C., & Collins, K. W. (1979). Evaluation of hierarchical mapping techniques as an aid to prose processing. *Contemporary Educational Psychology*, 4, 227-237.
- Hynd, C. R. (2001). Refutational texts and the change process. *International Journal of Educational Research*, 35, 699-714.
- Hynd, C. R., & Alvermann, D. E. (1986). The role of refutation text in overcoming

- difficulty with science concepts. *Journal of Reading*, 29, 440–446.
- Hynd, C. R., & Alvermann, D. E. (1989). Overcoming misconceptions in science: An online study of prior knowledge activation. *Reading Research and Instruction*, 28(4), 12-26.
- Hennessey, M. G. (2003). Probing the dimensions of metacognition: Implications for conceptual change teaching-learning. In G. Sinatra & P. Pintrich (Eds.), *Intentional conceptual change* (pp. 103–132). Mahwah, N.J.: Lawrence Erlbaum Associates.
- Inman, J. J., McAlister, L., & Hoyer, W. D. (1990). Promotion signal: Proxy for a price cut? *Journal of Consumer Research*, 17, 74-81.
- Ives, B., & Hoy, C. (2003). Graphic organizers applied to higher-level secondary mathematics. *Learning Disabilities Research & Practice*, 18, 36-51.
- Janiuk, R. M. (1993). The process of learning chemistry. *Journal of Chemical Education*, 70(10), 828-829.
- Johnson, M. A., Lawson, A. E. (1998). What are the relative effects of reasoning ability and prior knowledge on biology achievement in expository and inquiry classes? *Journal of Research in Science Education*, 35, 89-103.
- Kardash, C. M., & Scholes, R. J. (1996). Effects of pre-existing beliefs, epistemological beliefs, and need for cognition on interpretation of controversial issues. *Journal of Educational Psychology*, 88, 260-271.
- Kang, S., Scharmann, L. C., & Noh, T. (2004). Reexamining the role of cognitive conflict in science concept learning. *Research in Science Education*, 34 (1), 71-96.
- Kelly, G. J., & Green, J. (1998). The social nature of knowing: Toward a sociocultural perspective on conceptual change and knowledge construction. In B. Guzzetti & C. Hynd (Eds.), *Perspectives on conceptual change: Multiple ways to understand knowing and learning in a complex world*. (pp. 145-181). Mahwah, NJ: Lawrence Erlbaum Associates.
- Kikas, E. (1998). The impact of teaching on students' definitions and explanations of astronomical phenomena. *Learning and Instruction* 8(5), 439–454.
- Kintsch, W. (1989). Learning from text. In L. B. Resnick (Ed.) *Knowing, Learning, and Instruction*, 25–46.
- Kintsch, W. (1993). Information accretion and reduction in text processing: Inferences. *Discourse Processes*, 16, 193-202.

- Kintsch, W., & van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review*, 85, 363–394.
- Kools, M., van de Wiel, M. W. J., Ruiter, R. A. C., Crüts, A., & Kok, G. (2006). The effect of graphic organizers on subjective and objective comprehension of a health education text. *Health Education & Behaviour*, 33, 760-772.
- Kuhn, T. S. (1970) *Structure of scientific revolutions*, 2nd ed., Chicago: University of Chicago Press.
- Larkin, J. H., & Simon, H. A. (1987). Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science*, 11, 65-99.
- Lassiter, G. D., Briggs, M. A., & Bowman, R. E. (1991). Need for cognition and the perception of ongoing behavior. *Personality and Social Psychology Bulletin*, 17, 156-160.
- Lawson, A.E. (1978). The development and validation of a Classroom Test of Formal Reasoning. *Journal of Research in Science Teaching*, 15(1), 11-24.
- Lawson, A.E. (1985). A review of research on formal reasoning and science teaching. *Journal of Research in Science Teaching*, 22(7), 569-617.
- Lawson, A. E., & Thompson, L. D. (1988). Formal reasoning ability and misconceptions concerning genetics and natural selection. *Journal of Research in Science Teaching*, 25, 733-746.
- Leary, M. R., Sheppard, G. A., McNeil, M. S., Jenkins, T. B., & Barnes, B. D. (1986). Objectivism in information utilization: Theory and measurement. *Journal of Personality Assessment*, 50, 32-43.
- Linder, C. J. (1993). A challenge to conceptual change. *Science Education*, 77 (3), 293-300.
- Markman, E. M. (1979). Realizing that you don't understand: Elementary school children's awareness of inconsistencies. *Child Development*, 50, 643-655.
- Mandler, J. M., & Johnson, J. S. (1977). Remembrance of things parsed: Story structure and recall. *Cognitive Psychology*, 9, 111-151.
- Maria, K. (2000). Conceptual change instruction: A social constructivist perspective. *Reading & Writing Quarterly*, 16, 5-22.
- Martin, L. L., Ward, D. W., Achee, J. W., & Wyer, R. S. (1993). Mood as input: People have to interpret the motivational implications of their moods. *Journal of Personality and Social Psychology*, 64, 317-326.

- Meyer, B. J. F. (1975). *The organization of prose and its effects on memory*. Amsterdam: North-Holland Publishing Company.
- Morton, J. (1979). Facilitation in word recognition: Experiments causing change in the logogen model. In P. A. Kolers, M. E. Wrolstad & H. Bouma (Eds.), *Processing models of visible language, 1*, 259-268. New York: Plenum.
- Murphy, P. K., & Mason, L. (2006). Changing knowledge and beliefs. In P. A. Alexander & P. Winne (Eds.), *Handbook of educational psychology* (2nd ed., pp. 305–324). Mahwah, NJ: Lawrence Erlbaum Associates.
- Nagy, P., & Griffiths, A. K. (1982). Limitation of recent research relating Piaget's theory to adolescent thought. *Review of Educational Research, 52*, 513-556.
- Narayanan, N. H., Prabhakaran, V., Bunge, S. Christoff, K., Fine, E., & Gabrieli, J. (2005). The role of the prefrontal cortex in the maintenance of verbal working memory: an event-related fMRI analysis. *Neuropsychology, 19*, 223-232.
- Nesbit, J. C., & Adesope, O. O. (2006). Learning with concept and knowledge maps: A meta-analysis. *Review of Educational Research, 76*, 413-448.
- Neuberg, S. L., & Newsom, J. T. (1993). Personal need for structure: Individual differences in the desire for simple structure. *Journal of Personality and Social Psychology, 65*, 113-131.
- Novak, J.D., & Gowin, D.B. (1984). *Learning how to learn*. New York: Cambridge University Press.
- O'Donnell, A. M. (1994). Learning from knowledge maps: The effects of map orientation. *Contemporary Educational Psychology, 19*, 33–44.
- Oliva, J. M. (2003). The structural coherence of students' conceptions in mechanics and conceptual change. *International Journal of Science Education, 25*, 539-561.
- Oliver, K. M. (2009). An investigation of concept mapping to improve the reading comprehension of science texts. *Journal of Science Education and Technology, 18*(5), 402-414.
- Olson, K., Camp, C., & Fuller, D. (1984). Curiosity and need for cognition. *Psychological Reports, 54*, 71-74.
- Önder, I., & Geban, Ö. (2006). The effect of conceptual change texts oriented instruction on students' understanding of the solubility equilibrium concept. *Hacettepe University Journal of Education, 30*, 166-173.
- Palmer, D. H. (2003) Investigating the relationship between refutational text and

- conceptual change. *Science Education*, 87, 663–684.
- Paivio, A. (1986). *Mental representations: A dual coding approach*. New York: Oxford University Press.
- Park, J., & Han, S. (2002). Using deductive reasoning to promote the change of students' conceptions about force and motion. *International Journal of Science Education*, 24(6), 593-609.
- Pehrsson, R. S., & Denner, P. R. (1988). Semantic organizers: Implications for reading and writing. *Topics in Language Disorders Series*, 8(3), 24-37.
- Petty, R. E., & Jarvis, B. G. (1996). An individual difference perspective on assessing cognitive processes. In N. Schwarz & S. Sudman (Eds.), *Answering questions: Methodology for determining cognitive and communicative processes in survey research*, 221-257.
- Petty, R. E., Wells, G. L., & Brock, T. C. (1976). Distraction can enhance or reduce yielding to propaganda: Thoughtful disruption versus effort justification. *Journal of Personality and Social Psychology*, 34, 874-884.
- Petty, R. E., Cacioppo, J. T. & Goldman, R. (1981). Personal involvement as a determinant of argument-based persuasion. *Journal of Personality and Social Psychology*, 41, 847-855.
- Petty, R. E., & Cacioppo, J. T. (1986). The elaboration likelihood model of persuasion. In L. Berkowitz (Ed.). *Advances in Experimental Social Psychology*, 19, 123-205. New York: Academic Press.
- Piaget, J. (1970). Piaget's theory. In P. H. Mussen (Ed.), *Carmichael's manual of child psychology, Vol. 1 (3rd ed.)*, 703-732. NY: Wiley.
- Plotnick, E. (1997). Concept mapping: A graphical system for understanding relationship between concepts. ERIC Digest, ED407938.
- Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning & Instruction*, 12, 61–86.
- Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66, 211-227.
- Roadrangka, V., Yeany, R.H., & Padilla, M.J., (1982). *Group assessment of logical thinking*. University of Georgia.
- Roadrangka, V., Yeany, R.H., & Padilla, M.J., (1983). *The construction of a group*

- assessment of logical thinking (GALT)*. Paper presented at the 56th annual meeting of the National Association for Research in Science Teaching. Dallas, Texas, April, 5-8.
- Reinking, D., Pickle, M., & Tao, L. (1996). The effects of *inserted questions* and mandatory review in computer-mediated *texts* (Reading Research Rep. No. 50). Athens, GA: National Reading Research Center.
- Reznitskaya, A., & Anderson, R. C. (2002). The argument schema and learning to reason. In C. C. Block & M. Pressley (Eds.), *Comprehension instruction: Research-based best practices* (pp.319-334). New York: The Guilford Press.
- Rieber, L. P. (1992). *Computers, graphics and learning*. Madison, WI: Brown & Benchmark Publishers.
- Rieber, L. P. (1994). *Computers, graphics and learning*. Dubuque, Iowa: Brown & Benchmark Publishers.
- Robinson, D. H., & Kiewra, K. A. (1995). Visual argument: Graphic organizers are superior to outlines in improving learning from text. *Journal of Educational Psychology*, 87(3), 455-467.
- Robinson, D. H., & Schraw, G. (1994). Computational efficiency through visual argument: Do graphic organizers communicate relations in text too effectively? *Contemporary Educational Psychology*, 19, 399-415.
- Robinson, S. L., Katayama, A. D. (1999). When words are represented in memory like pictures: Evidence for spatial encoding of study materials. *Cotemporary Educational Psychology*, 24, 38-54.
- Roth, K. J. (1985). Conceptual change learning and students processing of science texts. Paper presented at the Annual Meeting of the American Research Association, Chicago, IL.
- Sadoski, M., Paivio, A., & Goetz, E. T. (1991). A critique of schema theory in reading and a dual coding alternative. *Reading Research Quarterly*, 26(4), 463-484.
- Sadowski, C. J., & Gulgoz, S. (1992). Internal consistency and test-retest reliability of the Need for Cognition Scale. *Perceptual and Motor Skills*, 74, 610.
- Sadowski, C. J. (1993). An examination of the short Need for Cognition Scale. *Journal of Psychology*, 127, 451-454.
- Scaife, M., & Rogers, Y. (1996). External cognition: How do graphical representations work? *International Journal of Human-Computer Studies*, 45, 185-213.
- Shimmerlik, S. M. (1978). Organization theory and memory for prose: A review of the

- literature. *Review of Educational Research*, 48(1), 103–120.
- Smith, E. L., Blakeslee, T. D., & Anderson, C. W. (1993). Teaching strategies associated with conceptual change learning in science. *Journal of Research in Science Teaching*, 30 (2), 111-126.
- Sorrentino, R. M., Bobocel, D. R., Gitta, M. Z., Olson, J. M., & Hewitt, E. C. (1988). Uncertainty orientation and persuasion: Individual differences in the effects of personal relevance on social judgments. *Journal of Personality and Social Psychology*, 55, 357-371.
- Spotts, H. (1994). Evidence of a relationship between need for cognition and chronological age: Implications for persuasion in consumer research. *Advances in Consumer Research*, 21, 238-243.
- Stull, A. T., & Mayer, R. E. (2007). Learning by doing versus learning by viewing: Three experimental comparisons of learner-generated versus author-provided graphic organizers. *Journal of Educational Psychology*, 99 (4), 808-820.
- Sungur, S., & Tekkaya, C. (2003). Students' achievement in human circulatory system unit: The effect of reasoning ability and gender. *Journal of Science Education and Technology*, 12, 59-64.
- Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th Ed.). Boston: Pearson Education.
- Taylor, B. M. (1980). Children's memory for expository text after reading. *Reading Research Quarterly*, 15, 399-411.
- Taylor, B. M. (1985). Toward an understanding of factors contributing to children's difficulty summarizing textbook material. In J. A. Niles & R. V. Lalik (Eds.), *Issues in Literacy: A research perspective*, 125-131. Rochester, NY: National Reading Conference.
- Taylor, B. M., & Samuels, S. J. (1983). Children's use of text structure in recall of expository material. *American Educational Research Journal*, 20, 517-528.
- Tobin, K. G., & Capie, W. (1981). The development and validation of a group test of logical thinking. *Educational and Psychological Measurement*, 41, 413-423.
- Tolentino, E., Curry, L., & Leak, G. (1990). Further validation of the Short Form of the Need for Cognition Scale. *Psychological Reports*, 66,321-322.
- Toulmin, S. (1972). *Human understanding: The collective use and evolution of concepts*. NJ: Princeton University Press.

- Tzeng, J. Y. (2010). Designs of concept maps and their impacts on readers' performance in memory and reasoning while reading. *Journal of Research in Reading, 33*(2), 128-147.
- Uzuntiryaki, E., & Geban, Ö. (2005). Effect of conceptual change approach accompanied with concept mapping on understanding of solution concepts. *Instructional Science 33*(4), 311-339.
- van de Broek, P., & Kendeou, P. (2008). Cognitive processes in comprehension of science texts: The role of co-activation in confronting misconceptions. *Applied Cognitive Psychology, 22*, 335-351.
- van Gelder, T. (2002). Argument mapping with Reason!able. *APA Newsletter: Philosophy & Computers, 2*(1), 85-90.
- van Dijk, T. A. (1980). *Macrostructure: An interdisciplinary study of global structures in discourse, interaction, and cognition*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- Vekiri, I. (2002). What is the value of graphical displays in learning? *Educational Psychology Review, 14*(3), 261-312.
- Venkatraman, M. P., Marlino, D., Kardes, F. R., & Sklar, K. B. (1990). The interactive effects of message appeal and individual differences on information processing and persuasion. *Psychology and Marketing, 7*, 85-96.
- Verplanken, B. (1991). Persuasive communication of risk information: A test of cue versus message processing effects in a field experiment. *Personality and Social Psychology Bulletin, 17*, 188-193.
- Waller, R. (1981). *Understanding network diagrams*. Paper presented at the annual meeting of the American Educational Research Association, Los Angeles.
- Wandersee, J. H., Mintzes, J. J., & Novak, J. D. (1994). Research on alternative conceptions in science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (1st ed., pp. 177-210). New York: MacMillan.
- Weary, G., Edwards, J. A. (1994). Individual differences in casual uncertainty. *Journal of Personality and Social Psychology, 67*, 308-318.
- Webster, D. M., & Kruglanski, A. W. (1994). Individual differences in need for cognitive closure. *Journal of Personality and Social Psychology, 67*, 1049-1062.
- Williams, K. A., & Cavallo, A. M. L. (1995). Reasoning ability, meaningful learning, and students' understanding of physics concepts. *Journal of College Science Teaching, 5*, 311-315.

- Winn, W. (1991). Learning from maps and diagrams. *Educational Psychology Review*, 3, 211-247.
- Winograd, P. N. (1984). Strategic difficulties in summarizing texts. *Reading Research Quarterly*, 19, 404-425.
- Wolfe, R. N., & Grosch, J. W. (1990). Personality correlates of confidence in one's decisions. *Journal of Personality*, 58, 515-534.
- Woloshyn, V. E., Paivio, A., & Pressley, M. (1994). Use of elaborative interrogation to help students acquire information consistent with prior knowledge and information inconsistent with prior knowledge. *Journal of Educational Psychology*, 86 (1), 79-89.
- Yürük, N. (2007). The effect of supplementing instruction with conceptual change texts on students' conceptions of electrochemical cells. *Journal of Science Education & Technology*, 16, 515-523.
- Zeitz, L.E., & Anderson-Inman, L. (1992). The effects of computer-based formative concept mapping on learning in high school science. Paper presented at the annual conference of the American Educational Research Association, San Francisco, CA.
- Zietsman, A.I., & Hewson, P.W. (1986). Effect of instruction using microcomputer simulations and conceptual change strategies on science learning. *Journal of Research in Science Teaching*, 23, 27-39.

APPENDICES

Appendix 1

Demography

1. Age: _____
2. Gender: _____
3. Highest level of education: _____
(*High school, Two-year diploma, Bachelor, Master or PhD*)
4. First language: _____
5. Years of studying in English-speaking countries if English is not your first language
(*if applicable*): _____

Appendix 2

Newton's Ideas about the Motion of Objects

We certainly learn from our experiences. Every time we experience an event, we may develop ideas that help us predict what will happen when a similar event occurs. We therefore have ideas about the motion of objects learned from our daily lives and use the ideas to predict what will happen to other objects under similar conditions. For example, when riding in a car that suddenly comes to a stop, you may become aware that your head is in danger of banging against the windshield. So the next time you experience a sudden stop, you may try to brace yourself to avoid getting hurt. According to Newton, an object that is carried is in motion, even if it appears to be at rest in relation to the person or thing carrying it. Every object inside a car is moving at the same speed as the car. When the driver is forced to step on the brakes suddenly, the driver, the passengers and other loose objects move forward at the same speed as the car was moving. These bodies will keep moving until something stops them. This might be the car's dashboard or windshield.

A rock moving in the vacuum of space will keep moving forever at the same speed unless some external force causes it to stop or change its speed. Newton explained that a moving object comes to a stop or begins to fall because outside (or external) forces act to change the speed or direction of the object's motion. A ball rolling across the floor, for example, slows down and then comes to rest after some time, even when there is no apparent external force acting on it. But actually there is an external force. This force is friction. Friction is a force that acts in the opposite direction of the ball's motion.

According to Newton, an object maintains its state of motion, either at rest or at constant speed in a straight line, unless acted upon by external forces. That is, when an object is in motion, it moves in a straight line assuming that no force is acting on it. For an object to change directions, it must be acted on by an outside force. For a ball to move in a circle, for instance, it must be acted on by an outside force such as a string. The tension in the string pulls on the ball and keeps it from moving in a straight line.

Imagine that a person is holding a stone at shoulder height while walking forward at a fast pace. What will happen when the person drops the stone? What kind of path will the stone follow as it falls? In fact, the stone will move forward as it falls, landing a few feet ahead of the point where it was dropped. Newton explained that the carried stone has forward motion. When the stone is dropped, it continues to move forward at the same speed as the walking person because no outside force (except air resistance) is acting to change its forward direction. Of course, as the stone falls forward it also moves downward at a steadily increasing speed. The forward and downward motions result in a curved path. In the same way, a ball fired horizontally will begin to move downward in a curved path from the moment it is fired because of the constant force of the earth's gravity.

In a word, every object persists in its state of being at rest or of moving uniformly straight forward unless it is compelled to change that state by an external force acting on it.

Appendix 3

True and False Ideas about the Motion of Objects

A rock moving in the vacuum of space will keep moving forever at the same speed unless some external force causes it to stop or change its speed.

Many people have wrong ideas about the motion of objects. These wrong ideas are called impetus theory. Impetus theory arose because people believe motion must have a cause. When people couldn't see a visible cause for an object to slow down or stop, they assumed there must be a force inside the object which was put there when the object was set in motion and gradually decays. This internal force was called impetus. Contrary to impetus theory, Newton proposed that a moving object comes to a stop or begins to fall because outside (or external) forces act to change the speed or direction of the object's motion. A ball rolling across the floor, for example, is slowed by friction. Friction is a force that acts in the opposite direction of the ball's motion. Therefore, it is incorrect to think that a rolling object stops or a ball falls to the ground because of the decay of internal force (impetus).

Newton believed that an object that is carried is in motion, even if it appears to be at rest in relation to the person or thing carrying it. For instance, every object inside a car is moving at the same speed as the car. When the driver is forced to step on the brakes suddenly, the people and other loose objects move forward at the same speed as the car was moving until something stops them.

According to Newton, but not impetus theory, when an object is in motion, it moves in a straight line assuming that no force is acting on it. For an object to change directions, it must be acted on by an outside force. For a ball to move in a circle, for instance, it must be acted on by an outside force such as a string. The tension in the string pulls on the ball and keeps it from moving in a straight line.

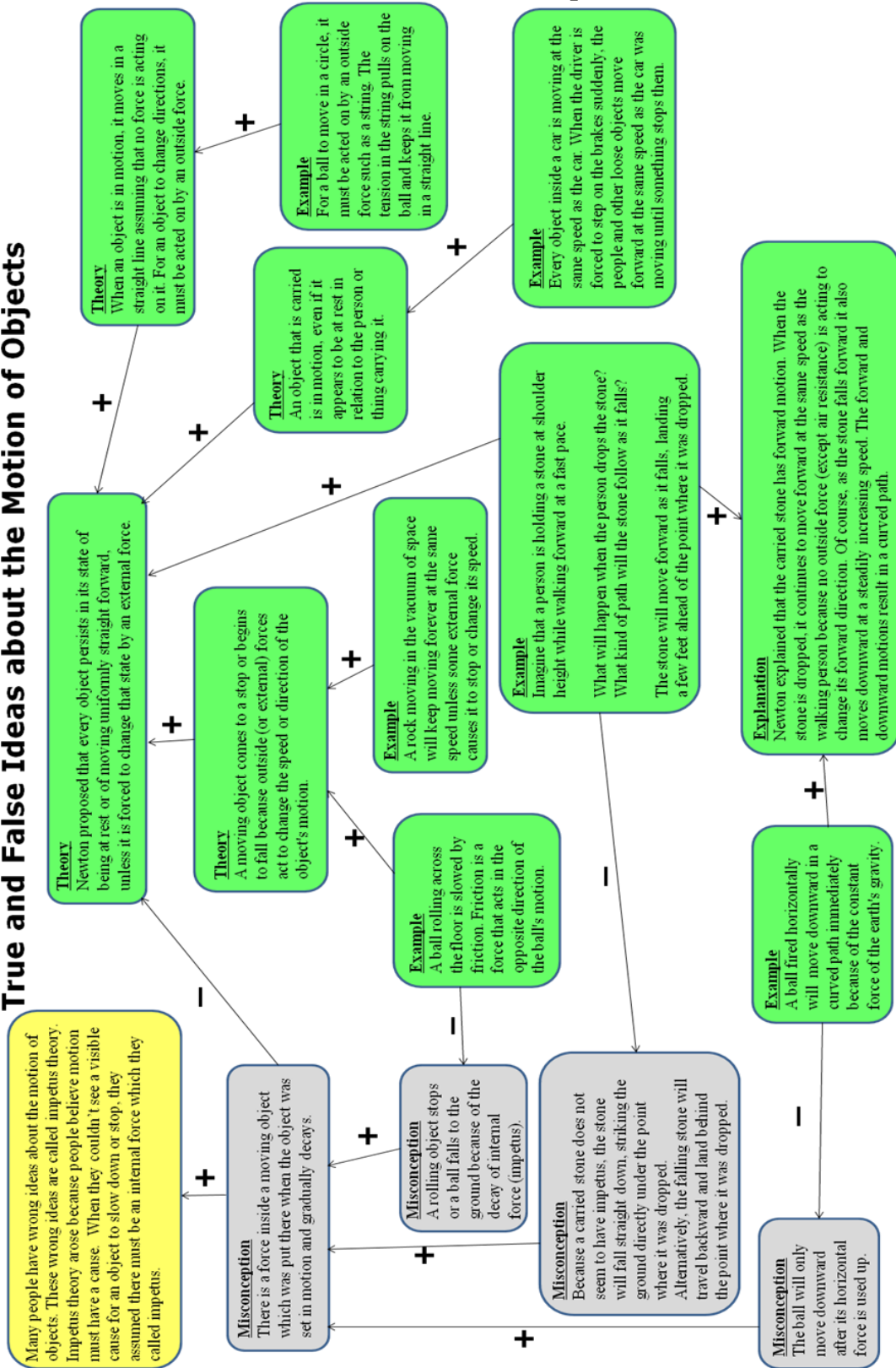
Imagine that a person is holding a stone at shoulder height while walking forward at a fast pace. What will happen when the person drops the stone? What kind of path will the stone follow as it falls? Because a carried stone does not seem to have impetus, many people say that the stone will fall straight down, striking the ground directly under the point where it was dropped. Some even believe that the falling stone will travel backward and land behind the point where it was dropped. Actually, the stone will move forward as it falls, landing a few feet ahead of the point where it was dropped. Newton explained that the carried stone has forward motion. When the stone is dropped, it continues to move forward at the same speed as the walking person because no outside force (except air resistance) is acting to change its forward direction. Of course, as the stone falls forward it also moves downward at a steadily increasing speed. The forward and downward motions result in a curved path. In the same way, a ball fired horizontally will begin to move downward in a curved path from the moment it is fired because of the constant force of the earth's gravity. This fact is not consistent with impetus theory, which says the ball will only move downward after its horizontal force is used up.

In a word, every object persists in its state of being at rest or of moving uniformly straight forward, unless it is compelled to change that state by an external force acting on it.

Appendix 4

Refutational Map

True and False Ideas about the Motion of Objects



Appendix 5

Free Recall Test

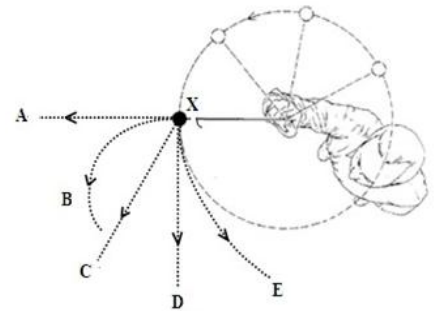
Write down everything you can remember from the material you studied in this experiment. Try to write in complete **sentences** but not to worry about spelling or grammar.

A large, empty rectangular box with a thin black border, intended for the student to write their free recall test answers. The box occupies most of the lower half of the page.

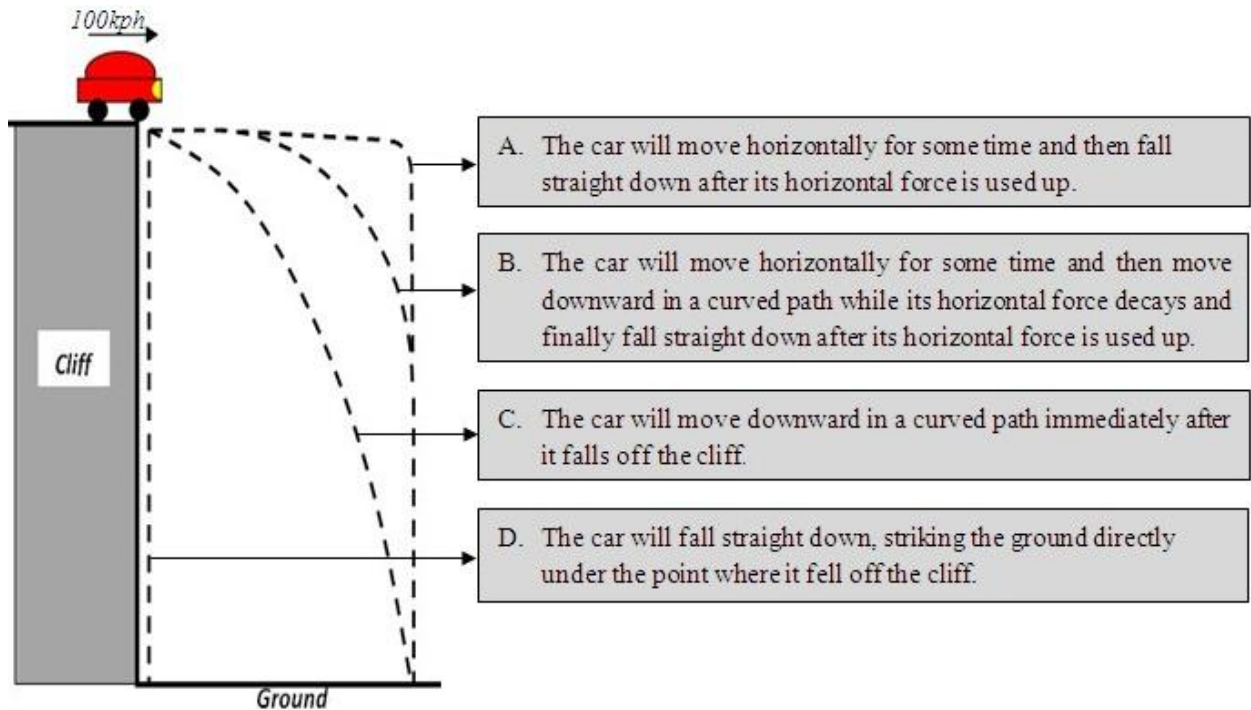
Appendix 6

Transfer Essay Questions

1. Vehicles are required to provide adequate *head restraints*.
In which circumstance(s) would we need them most? Why?
(Please use Newton's terms for explanation)
2. A person is walking forward at a brisk pace carrying a stone at shoulder height.
 - (1) According to Newtonian mechanics, where should the stone fall if dropped, in relation to the point where it was dropped?
 - (2) Why would this happen?
3. A rubber ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the accompanying diagram. At the point X indicated in the figure, the string suddenly breaks near the ball.
 - (1) If these events are observed from directly above as in the figure, which path would the ball continue to follow after the string breaks?
 - (2) Why would the ball take this path?
4. A bowling ball is pushed at high speed over the end of a diving board.
 - (1) Ignoring air resistance, how would you describe the trajectory (path) of the ball?
 - (2) What force(s) is (are) acting on the ball after receiving the push but before touching the ground?



5. A car traveling at 100 kilometers per hour (kph) drives off a cliff, as shown in the diagram below.
- (1) Ignoring the resistance of air, choose the most possible path (A, B, C or D) that the car would take.
 - (2) Write the explanation of the reasoning behind your answer.

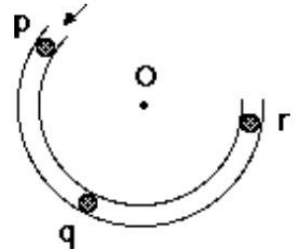


Appendix 7

Transfer Multiple-Choice Questions

Please choose the best answer you think for each question.

1. *The accompanying figure shows a frictionless channel in the shape of a segment of a circle with center at "O". The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at "p" and exits at "r."*



Consider the following distinct forces:

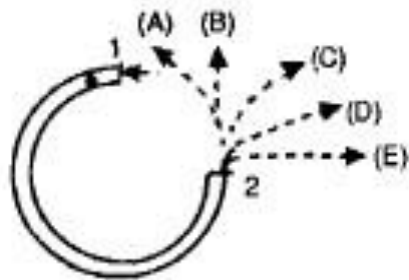
1. A downward force of gravity.
2. A force exerted by the channel pointing from q to O.
3. A force in the direction of motion.
4. A force pointing from O to q.

Which of the above force(s) is (are) acting on the ball when it is within the frictionless channel at position "q"?

- (A) 1 only
- (B) 1 and 2
- (C) 1 and 3
- (D) 1, 2, and 3
- (E) 1, 3, and 4

My Answer is _____

2. The accompanying diagram depicts a semicircular channel that has been securely attached, in a horizontal plane, to a table top. A ball enters the channel at "1" and exits at "2". Which of the path representations would most nearly correspond to the path of the ball as it exits the channel at "2" and rolls across the table top?

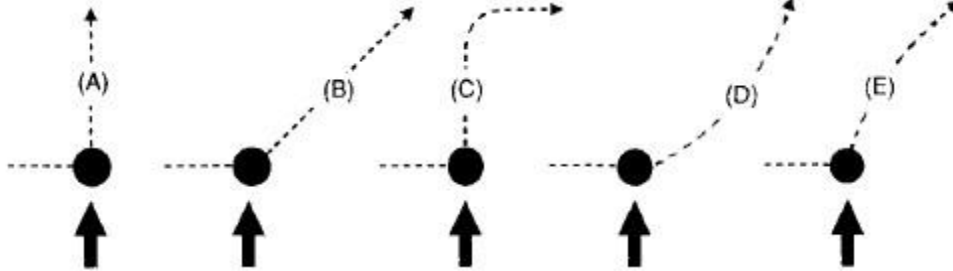


My Answer is _____

3. The diagram depicts a hockey puck sliding with a constant speed, from point "a" to point "b" along a frictionless horizontal surface. Forces exerted by the air are negligible. You are looking down the puck. When the puck reaches point "b", it receives an instantaneous horizontal "kick" in the direction of the heavy print arrow.



Along which of the paths below will the hockey puck move after receiving the "kick"?



My answer is _____

4. Along the frictionless path you have chosen in question 3, the speed of the puck after receiving the kick:

- (A) is constant
- (B) continuously increases
- (C) continuously decreases
- (D) increases for a while and decreases thereafter
- (E) is constant for a while and decreases thereafter

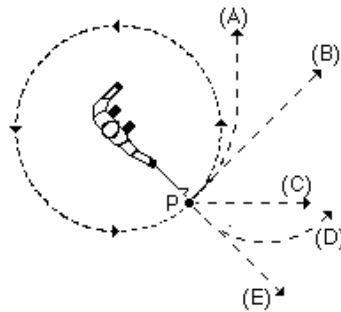
My answer is _____

5. Along the frictionless path you have chosen in question 3, the main force(s) acting on the puck after receiving the kick is (are):

- (A) a downward force of gravity
- (B) a downward force of gravity, and a horizontal force in the direction of motion
- (C) a downward force of gravity, an upward force exerted by the surface, and a horizontal force in the direction of motion
- (D) a downward force of gravity and an upward force exerted by the surface.
- (E) none (no forces act on the puck)

My answer is _____

6. A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the diagram below. At the point P indicated in the figure, the string suddenly breaks near the ball. If these events are observed from directly above as in the figure, which path would the ball most closely follow after the string breaks?



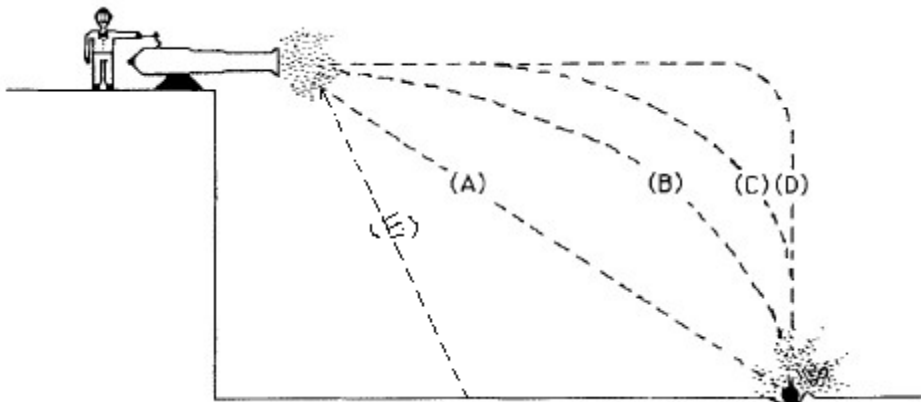
My answer is _____

7. A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are):

- (A) a downward force of gravity along with a steadily decreasing upward force
- (B) a steadily decreasing upward force from the moment it leaves the boy's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the object gets closer to the earth
- (C) an almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on the way down there is only a constant downward force of gravity
- (D) an almost constant downward force of gravity only
- (E) none of the above. The ball falls back to ground because of its natural tendency to rest on the surface of the earth

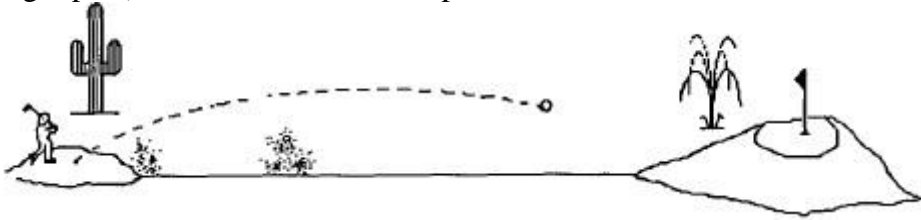
My answer is _____

8. A ball is fired by a cannon from the top of a cliff as shown in the figure below. Which of the paths in the diagram below best represents the path of the cannon ball?



My answer is _____

9. A golf ball driven down a fairway is observed to travel through the air with a trajectory (flight path) similar to that in the depiction below:



Which following force(s) is (are) acting on the golf ball during its entire flight?

1. The force of gravity
2. The force of the "hit"
3. The force of air resistance

- (A) 1 only
(B) 1 and 2
(C) 1, 2, and 3
(D) 1 and 3
(E) 2 and 3

My answer is _____

Appendix 8



SIMON FRASER UNIVERSITY
THINKING OF THE WORLD

H. Weinberg, Ph.D.
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Expedited Approval

Date	File	Approval	Principal Investigator
13 June 2010	[2010s0334]	Approved	Liu, Qing
Risk	Title		Start
Minimal	Conceptual Change with Refutational Map		13 June 2010
SFU Status	Department / School	Supervisor	End
Graduate Student	Education	Nesbit, John	12 June 2013

Hello Quing,

Your application has been categorized as 'Minimal Risk' and approved by the Director, Office of Research Ethics in accordance with University Policy r20.01. (<http://www.sfu.ca/policies/research/r20.01.htm>).

The Research Ethics Board reviews and may amend decisions made independently by the Director, Chair or Deputy Chair at the regular monthly meeting of the Board.

Please acknowledge receipt of this Notification of Status by email to dore@sfu.ca and include the file number as shown above as the first item in the Subject Line.

You should get a letter shortly. Note: All letters are sent to the PI addressed to the Department, School or Faculty for Faculty and Graduate Students. Letters to Undergraduate Students are sent to their Faculty Supervisor.

Good luck with the project,

Hal Weinberg, Ph.D.
Director, Office of Research Ethics.

Hal Weinberg, Ph.D.
Director, Office of Research Ethics