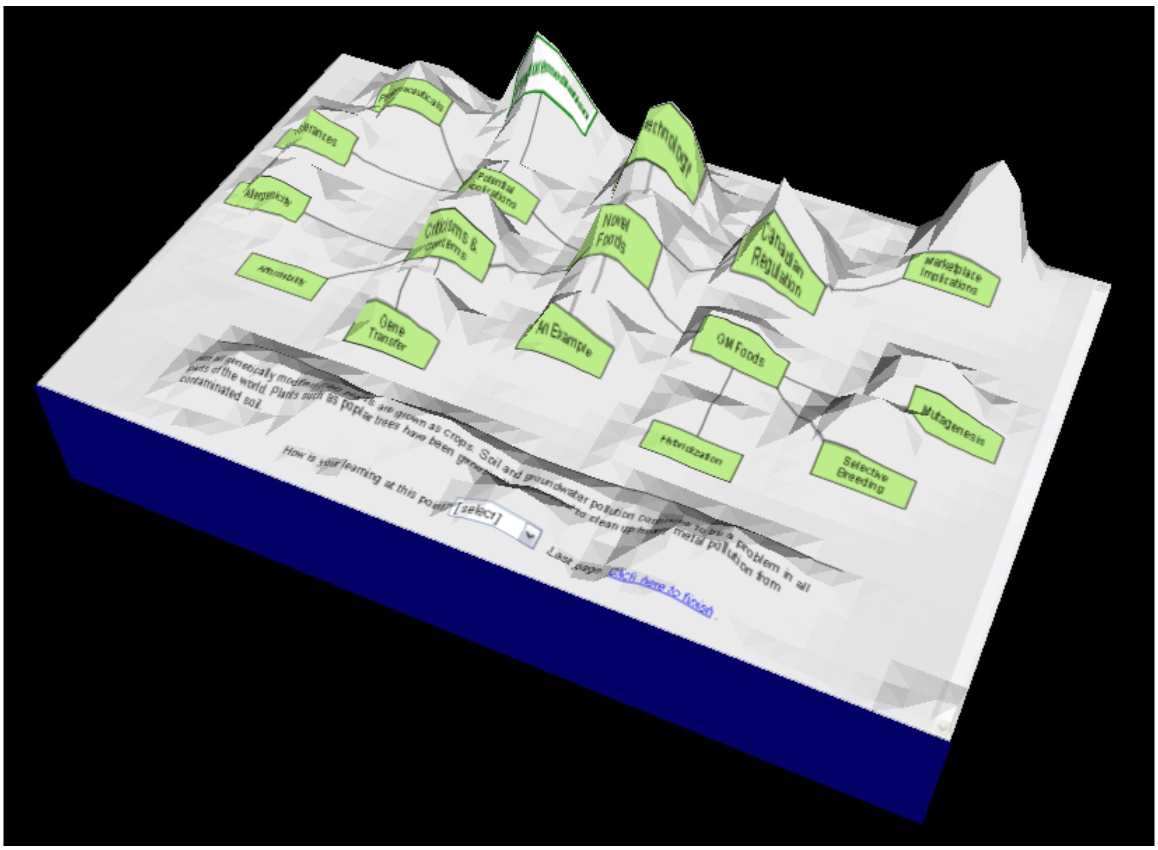

Potential Applications
Criticisms & Concerns
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Canadian Regulation
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Gene Transfer
An Example
GM Foods
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How is your learning at this point? [select]
Last page: Click here to finish

Investigating Learning with a Navigable Concept Map

by

Stephanie Tset Lee Chu

M.A., Simon Fraser University, 1999
B.A., Simon Fraser University, 1994

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

In the
Faculty of Education

SIMON FRASER UNIVERSITY

Summer 2008

APPROVAL

Name: Stephanie Tset Lee Chu

Degree: Doctor of Philosophy

Title of Thesis: Investigating Learning with a Navigable Concept Map

Examining Committee:

Chair: Dr. Cheryl Amundsen
Associate Professor

Dr. Phil Winne
Senior Supervisor

Dr. John Nesbit
Member

Dr. Vive Kumar
Member

Dr. John Bowes
External Examiner
Professor, School of Interactive Arts & Technology

Dr. John Walsh
Examiner
Professor, Faculty of Education, University of Victoria

Date Defended/Approved: August 1, 2008

ABSTRACT

Navigable concept maps are a type of graphical overview and a relatively new learning tool that may serve several interrelated functions while learners study online: as a graphic organizer, navigational tool, pathway indicator, actual material-to-be-learned, and a means to self-monitor and review during studying and at the end of a study period. Few studies have examined navigable concept maps, although many studies have investigated different types of organizers with varied learner control. Studies have focused primarily on achievement outcomes and explanations based on cognitive load and individual differences. The results are inconsistent and the implications, unclear.

The present study aimed to achieve three key goals: (1) to examine whether knowing one's location within the navigable concept map or control over topic sequence affects online studying and achievement, (2) to investigate the relationship between metacognitive awareness, self-regulated learning, individual differences, and studying and achievement, in relation to navigable concept map use; and, (3) to observe the studying process and learners' experiences using the map.

Sixty-three university students were assigned to one of three treatment groups: learner-, peer- or instructor-controlled topic sequence. The participants studied the topic of novel foods through a navigable concept map and related text. Descriptive data, scores on the Metacognitive Awareness Inventory (MAI), self-ratings of learning, time on each study page, eye-movement and fixation data, scores for a recall and application achievement measure and responses to a studying experience questionnaire were collected.

Although there were no statistically detected effects of learner control over topic sequence, the results supported previous findings where prior knowledge, motivation, and interest influenced perceptions of learning and achievement. Topic selection sequence for the learner control group suggested patterns in students' approaches to studying via a concept map. Limited eye-movement data (n = 35) offered a glimpse of how map use varied over the study period and how learners attended to the text more than the map. These, combined with self-report data, provided insight into the potential of navigable concept maps and considerations for future designs to support the studying process and self-regulation, and in turn, achievement.

Keywords: dynamic concept map; learner control; self-regulated learning; web-based instruction; eye fixations; hypermedia

Subject terms: instructional systems design; metacognition; internet in education; eye movements; computer-assisted instruction; learning, psychology of

…To My Family

ACKNOWLEDGEMENTS

It has been an eventful several years. Thank you to everyone in my professional and personal life, including those who are no longer with me who have aided this voyage.

I wish to extend my thanks to my committee, as Phil Winne, John Nesbit and Vive Kumar as each provided unique contributions to the doctoral process and saw me through to the end – special thanks to Phil for ensuring that I met high standards and John for joining the committee at a critical juncture and providing insight and thoughtful feedback; Cheryl Amundsen for being an examiner on my comps and the chair at my defence; John Bowes, Rob Woodbury, and the SIAT program for their support and use of the Interactivity Lab and eye-movement equipment, Hector Larios for his limitless patience in training me and providing consultation on the eye-tracker, and my external examiners John Walsh and John Bowes for their positive recognition of my work, thought-provoking questions and comments, and for passing me with no revisions! ☺

My journey was facilitated by the encouragement and support from colleagues and friends near and far whom I had met and worked with over the years. Special thanks to:

- Colleagues from the former CADE & AMTEC (now CNIE), ETUG, UCIPD, EDC, STLHE, *many* post-secondary institutions, educational associations and beyond
- Friends and colleagues from across the SFU community, particularly in the LIDC, Faculty of Education, Student Services, WIL, CODE, IT Services, FASS, FAS, and the Library for the people and their commitment to providing avant-garde services
- David Kaufman, Bill Glackman, John Moore and Bill Goodman of the LIDC, and
- My cheerleading, support group: Angela Runnals, Kitty Gustafson, Jason Toal, Sylvia Currie, Linda Hof, Shelley Sluggett, Denise Stockley, Judy Lew, Nancy Johnston, Andrea Sator, John Grant, Joan Collinge, Brian Burtch, Stephanie Dayes (+ for piloting & editing), Cindy Xin (+ for my mock-defence), Mauvereen Walker (+ for reminding me to breath) and friends who have been monitoring my progress such as through Facebook and sending good mojo.

I greatly appreciate the advice and aid my dear friends have provided me in *countless* ways (and times!): Dianne Jamieson-Noel, Chris Groeneboer and Dennis Humphrey.

I am grateful for my family's patience, support and understanding over the years and for all the times I went "underground". Thank you Mom, Dad and Mum (and my late Uncle John); also to Noidy for offering her feline serenity and constant companionship throughout the odd hours and long nights of all three of my degrees. Finally, my heartfelt gratitude to Mike – my anchor, who played a remarkable number of roles from programmer, pilot study participant, editor, counsellor, chef, single parent, house-keeper, chauffeur, photocopier, to most importantly, my best friend.

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GLOSSARY

Advance organizers (AO)	An overview presented prior to learning to help learners to gain a sense of the overall content to be studied, to help recall prior knowledge and to organize the new information.
Cognitive load	The burden placed on working memory that results from task demands on one's limited working memory.
Cognitive load theory	Describes the working memory system and how tasks and effort make demands on one's limited working memory.
Concept maps	A type of structured overview. Diagrams representing key ideas and their relationships through node-link connections. A related term is *knowledge maps*, which are in essence a type of concept map with directional links and a common set of labeled links to connect ideas.
Construction Integration Model	Proposes that for recall tasks, learners can achieve good performance from a good textbase representation created from its semantic content and that mirrors the text's organization.
Dual coding model	Describes two independent, yet interconnected and concurrent cognitive systems in working memory: verbal and visual.
Fixation duration	A related measure to fixation frequency where the sum of the length of individual fixations in milliseconds is recorded when one looks at a specific visual area. Generally the range is between 200-500 *ms.*
Fixation frequency	The total number of fixations a person makes on an area of the visual field.
Fixation point	Necessary to process details and indicate where attention is directed, when the eyes are aimed at a fixed point (*see black dots in Figure 2*).
Free group	Condition group where participants controlled the topic sequence. Identified by ID numbers in the 100-range.
GazeTrails	Artefact of the GazeTracker™ application that shows a test subject's ocular path via a coloured path that connects fixation points (*Figure 2*).

Graphic organizer (GO)	An advance organizer in image form, which have the added benefit of using their spatial format to denote relationships among concepts. In this study, I use the term more generally to mean an organizer that aids students with the content, which appears as an image.
Hyperlink	Commonly known as a *link*, is a reference or navigational element in a document connected to another section of the same document, another document or a specific section of another document, thereby providing the reader with the referred information
Hypermedia environments	Computer-based environments containing multimedia (text, sound, graphics, video) in one document.
Hypertext	An electronic form of text presentation that supports non-linear linking of nodes or chunks of text.
Knowledge of cognition	Perceptions about one's strengths and weaknesses in learning, awareness of strategy use, and the effectiveness of one's learning under certain conditions.
Learner control	The extent to which learners exercise control over their learning environment. Differs across research studies and may be operationalized as (1) sequencing, where learners decide on the order information is accessed, (2) content selection, determining which information to receive, (3) representation control, how content is displayed, and (4) pacing, the speed by which information is presented.
Clockwise group	Condition group where participants do not control topic sequence. Instead, they received an instructionally rationalized sequence and proceeded through the topics in a clockwise manner, starting from the centre. Identified by 200-range ID numbers.
LookZones	Pre-identified areas on a screen used to filter the recorded eye-movement data and provide measures for that particular area.
Metacognition	The awareness and ability to reflect upon, understand and adapt one's learning necessary for self-regulated learning.
Navigable concept map	A *navigational map* in the form of a concept map.
Navigational maps	An image that provide a high-level overview of the content and can help learners to locate information in electronic texts, to identify their location within the content they are studying, and sometimes to serve as the actual means for navigation. They may appear in the form of text or images such as concept maps, which also illustrate the relationship among topics.

Network maps	Similar to a concept map as it identifies key concepts and subtypes through an enclosed circle or box. More complex in that interrelationships among all concepts are described using labeled lines or links.
Regulation of cognition	Entails planning, information management strategies, monitoring and debugging while learning.
Scanpath	The order individual elements are viewed.
Schemas	Foundational blocks of knowledge that are internal representations of concepts, events or objects.
Self-regulated learning	An active process comprising four stages: (1) task definition, (2) goal setting and planning, (3) enactment, and (4) adaptation.
Structured overviews	Have a spatial arrangement of concepts, listing the important concepts at the top, followed by subtypes underneath and further subtypes thereafter. A *concept map* is an example.
Text signals	Information that is highlighted or cued within text that can take the form of an overview, headings, or summary.
Yoked group	Condition group where participants followed a predetermined topic sequence defined by a preceding "free" condition participant. Identified by 300-range ID numbers (e.g. participant #303 viewed the topics in the order that #103 selected).

CHAPTER I: RATIONALE & RESEARCH AIMS

Introduction

Read or scan any educational or instructional technology journal or conference proceeding and you will find that the scope of educational research is expansive with current research investigating a wide range of computer-based or web-based learning tools, learning environments, and content formats such as multimedia, their design and influences on learning (cf. Boot, van Merriënboer & Veerman, 2007; Kaper & Kinzer, 2007, Verleur, Verhagen & Heuvelman, 2007). Even though our knowledge about learning using computer-based or online instruction is expanding, instructors often provide at least some to-be-learned text content in the form of *hypertext*. Hypertext is an electronic text format that supports linking of nodes or chunks of text. Proponents of online learning argue that hypertext allows learners flexibility to connect new knowledge with existing frameworks and to do so in personally meaningful ways (cf. Dillon & Gabbard, 1998; Scheiter & Gerjets, 2007; Williams, 1996). However many learners have difficulties reading and learning from hypertext (Niederhauser & Shapiro, 2003). The lack of predetermined ordering of content may necessitate new learning strategies from learners. Self-monitoring and evaluating of one's comprehension likely are even more important in this situation than with conventional text (Goldman, 1996).

Over a decade ago, Leu and Reinking (1996) observed that evidence and theory rarely served as a basis for designing electronic environments. It was not clear then or now, whether students' processing of online content involves specific learning strategies for hypertext content (van Oostendorp & de Mul, 1996). Current practices in developing online materials and related guidelines continue to suggest that developers have only limited understanding of (1) how learners attend to and use online text features, such as hyperlinks, navigable outlines and concept maps; (2) the effects of these components; or (3) the conditions for successful learning. Immersed in online learning and curriculum development for over a decade, I have observed little change in our understanding of online content and its design. As well, I argue that reported research on hypertext environments and online learning sometimes lacks theoretical grounding or reliable evidence.

From a broad range of possible learning aids, I chose to focus on one to investigate its use during the studying process and its effects on learning: Specifically, I focused on a map that aids learners with navigation presented in the form of a *navigable concept map*. Such maps provide affordances specifically for online learners by drawing upon the functionality of interrelated tools: graphic organizers, concept maps, and navigational maps. Very few researchers have examined an online learning tool with these functions (c.f. Puntambekar and colleagues; Chang, Sung & Chiou, 2002) and those that have, do not describe the maps by drawing from multiple fields of research.

A navigable concept map may serve many functions. First, it can help learners with the flexible ordering of hypertext by providing a visual high-level overview of the content taking a very loosely defined graphic organizer role. Acquiring top-level information about a text has been associated with better recall and comprehension (Jonassen, 1986). At this point, I must digress to explain my use of terminology. I recognize that there is research devoted to the more stringent definitions of advance organizer and graphic organizer. An *advance organizer (AO)* serves as a framework for learning new information and consists of information presented at the start of a session to help learners identify the main ideas, their interconnections, their fit within the overall topic, connections to prior knowledge and to activate prior knowledge (Langan-Fox, Platania-Phung & Waycott, 2006; Mayer, 2003). *Graphic organizers (GO)* are advance organizers which have the added benefit of using their spatial format to denote relationships among concepts. Such displays appear to help learners to organize information in memory (e.g. Lorch, Lorch, & Inman, 1993), and have generally been found to facilitate recall (Corkill, 1992).

However, a review of the literature has shown that the meaning of these terms has become blurred and the terms used broadly and synonymously with other types of learning aids. In terms of graphic organizers in particular, the lines between it and other visual organizers are unclear. For example, Dee-Lucas and Larkin's (1995) research on interactive overviews is widely cited. de Jong and van der Hulst (2002) refer to Dee-Lucas and Larkin's interactive overview as a "visual overview", "visual display" and "graphical display" throughout their article. Meanwhile, Langan-Fox, Waycott and Albert (2000) cite Dee-Lucas and Larkin on "advance organizers", when by definition, the interactive overview is not. The interactive overview is available prior to learning, but it remains in place throughout the session to aid students' navigation.

Although graphic organizers had a specific definition and format in the past and certain lines of research, I contend that it has become a more generic term describing a visual and structured representation of information. It can appear prior to studying and it can persist throughout a study session. When I refer to graphic organizers and advance organizers (or organizers) in this dissertation, I do so in generic terms, that both are information to help learners identify the main ideas, their interconnections, and their fit within the overall topic and to serve as a framework for learning new information. The graphic organizer however, does so as an image.

Therefore, a navigable concept map acts as a type of graphic organizer at the start of a study period. Then, the map may enable learners to capitalize on the representation of key ideas and their relationships through node-link connections. Maps help learners to develop an understanding of the concepts before they can represent their own thinking in a self-generated map for example (Vekiri, 2002). These *concept maps* are a type of organizer in the form of a diagram (Novak & Gowin, 1984) and can provide a framework and more concrete representation of the information to learners, which in turn help them to better organize and remember the information (Vekiri, 2002). A map may aid navigation, but is not sufficient for effective learning. Learners need to actively employ maps to monitor their strategy use while learning, particularly when studying hypertext (Deimann & Keller, 2006). Learners may employ concept maps while engaging in *metacognition*, the awareness and ability to reflect upon, to understand, and to adapt one's learning, which is an essential component of self-regulated learning (Paris, 2003).

Navigable concept maps may also serve as a navigational aid for learners. The potential to access information through multiple entry points is also a challenge of studying online text; learners can experience disorientation and become confused about their location with the networked and nested content (Cress & Knabel, 2003). Thus, much research has focused on different navigational tools to address this problem (Scheiter & Gerjets, 2007). *Navigational maps* provide a high-level overview of the content in a relational format and can help learners to locate information in electronic texts (Dee-Lucas & Larkin, 1995), to identify their location within the content they are studying, and sometimes to serve as the actual means for navigation. Furthermore, navigational map use entails *learner control*, the extent to which learners exercise control over their learning environment through a variety of ways such as navigating through self-selected topics (Miller, 1997; Scheiter & Gerjets, 2007). Reported benefits of learner control include deeper processing, development of one's own cognitive structures (Williams, 1996), and evolving skills in self-regulation (Azevedo, 2005).

I refer to the map in this study as a *navigable concept map* because it builds on research investigating graphic organizers, concept maps, and navigational maps; it also enables learners to capitalize on the benefits of each tool as described above, depending on their level of self-regulation and metacognition (Schwartz, Andersen, Hong, Howard & McGee, 2004). The concept map in the present study also acts as a navigational tool whereby the nodes signal one's location and progress, and serve as a means for topic selection and navigation to proceeding topics. Signaling may assist learners by reducing the number of cognitive resources expended on selecting information and processing the text organization, thereby enabling learners to have more resources to integrate the new information with prior knowledge (Mautone & Mayer, 2001).

Whereas navigational map research has included text-based and graphic maps, this study utilizes solely a graphical map and specifically, a concept map that identifies key topics and their connections. The freedom to decide on the topic order is a form of learner control, which benefits learning by enabling learners to choose a learning path that best meets their needs (Miller, 1997). In light of a broad range of operational definitions for learner control, the pace of studying and the ability to select topics in a desired order are the learner control foci of this study.

Directions, Issues, and Considerations

The upcoming literature review outlines the different fields in which navigable concept map research is grounded. In reviewing existing research directions, methodological, theoretical, and conceptual issues became apparent and led to considerations for improving research in this relatively young field of study and for designing the present study.

The first issue concerns our limited knowledge about how students learn online in terms of their studying process and use of specific tools such as navigable concept maps. Online text differs from traditional text through its branching and cross-references, which allow learners to access information through multiple entry points and selective navigation (van Oostendorp & de Mul, 1996). Learners have attributed to concept maps: better recall of central ideas, schema development, and the use of active processing strategies (Dee-Lucas & Larkin, 1995). Examining the way learners use maps may provide insight into their cognitive processes.

When researchers have applied cognitive theory to organizer or navigational map research, they frequently cite cognitive load as a theoretical explanation for how maps and graphics work, even though it is difficult to capture and examine data to support the notion of cognitive load (Scott & Schwartz, 2007). *Cognitive load* refers to the burden placed on working memory that results from task demands on one's limited working memory (Sweller, 1988). Map use can be investigated through other cognitive theories and learning models. For instance, being aware, able to reflect upon, to understand, and to adapt one's learning are essential skills for self-regulated learning and success in learning, but are especially critical for studying online in this newer, less familiar open environment (Deimann & Keller, 2006). Metacognitive learners plan, sequence, and monitor their learning to directly enhance performance (Schraw & Dennison, 1994) and moderate success in most learning environments (Hartley & Bendixen, 2003; Schraw, 1998). Metacognitive ability influences one's learning strategies and response to self versus system controls (Yong, 1996). However, rarely do studies investigate map use in the context of metacognitive skill level; Eckhardt, Probst and Schnotz (2003), and Scott and Schwartz (2007) are exceptions. These researchers suggest that by working with instructional materials such as concept maps, learners engage in decision-making and self-regulation; thus, learner control may evolve self-regulatory skills. Additional research examining concept map use through a metacognitive and self-regulated learning lens can shed further light on online learning processes.

Learner control, the means for navigation, and knowing one's location also require further attention. Although learners are empowered to manage their own learning, the mixed reported effects are a result of different types of control ranging from decisions on what to access or receive, presentation type, or the pace materials are presented (Reeves, 1993; Scheiter & Gerjets, 2007). An added dimension is the level of learner versus system control. Benefits appear to be dependent on a number of individual differences (metacognitive level, ability, prior knowledge, etc.) with low-ability or low prior knowledge learners gaining from some system control or learner control with advisement to scaffold their learning (Dillon & Gabbard, 1998). Few studies examine learner control in online concept map use and even less so with navigable concept maps. In some studies, learners interacted directly with the organizers to move within the online content (c.f. Puntambekar and colleagues); while in other studies, the means to navigate is inconsistent between the different types of organizers (e.g. Dee-Lucas & Larkin, 1995) or is not mentioned at all. Inconsistent or uncontrolled navigational differences may confound findings: not only may we be unable to discern whether reported effects resulted from the type of overview used, but the navigational capabilities afforded by the organizer may have been an additional factor. Another confound in previous learner control research was the varying levels of students' access to information and the learners' missing key information resulting from learner control (Williams, 1996). Thus, in the present study, learners were required to progress through all of the content.

As previously mentioned, students sometimes report disorientation and confusion when studying online. Adding to the complexity of learner control and navigation is the challenge of knowing one's location within the content (Cress & Knabel, 2003). Some online environments include breadcrumb trails, or text indicating the location of the current topic, but few studies incorporate more global, visual depictions of the subject matter and even fewer provide a dynamically generated illustration of the current, visited, and not-yet-visited topics (Puntambekar and colleagues being one of the exceptions). Research on graphic organizers such as maps, show that they are computationally efficient when their interpretation depends on the visual system because it occurs with minimal computation and unravelling and minimized cognitive load (Robinson & Kiewra, 1995; Vekiri, 2002).

These maps may reduce cognitive load by helping learners to orient themselves with less effort (Puntambekar, Stylianou, & Hübscher, 2003). Knowing one's pathway, location and seeing the connections between concepts and engaging in decision-making may evolve self-regulation (Scott & Schwartz, 2007). Additional research can enable educators to better understand the extent to which learner control over navigation and knowledge of one's location benefit online learners. Understanding these steps provides insights into the process of learning and the decisions and actions learners make based on their self-monitoring.

As suggested in the preceding section of this chapter, many types of organizers and maps exist, and studies have employed organizers that vary in format: text-based lists and hierarchical or relational graphics (e.g. Dee-Lucas & Larkin, 1995; Potelle & Rouet, 2003). However, a resulting issue with this research is that the organizers might not be comparable to one another. Based on the *dual coding model* where working memory consists of independent and interconnected visual and verbal systems, a text organizer may be processed in a different cognitive system than the graphic organizer, and thus, affect achievement results. Furthermore, if a study employed organizers that use different working memory stores and examined the effects of other variables such as navigational control, it would be difficult to clearly attribute outcome differences to either the organizer or the level of control. Thus, using one type of map or organizer is preferred when studying an aspect of the learning process such as navigation.

Lastly, some general methodological limitations exist in current research. Few studies (e.g. Puntambekar et al., 2003) examine how learners use maps *while* studying, but focus rather on end-results through outcome measures. Some studies understate or omit reporting on learners' conscious decision-making and their rationales for the choices they make. Furthermore, many studies employ only one outcome measure, usually a recall measure that may not actually require the more flexible learning approaches available through online learning (Goldman, 1996). As a result, researchers may not have observed the potential effects of the online environment. Applying higher-order cognitive measures may bring online advantages to the forefront.

Framing the Present Study: Purpose and Significance

Studying online materials is not the same as studying materials in print. To be successful, learners require more engagement with the learning materials and active decision-making, monitoring, and strategy use (Shader, 1999). Learning aids may facilitate the ability to self-monitor and self-evaluate (Eckhardt et al., 2003; Scott & Schwartz, 2007). Although research has made advances, there are gaps in educators' understanding about how students learn online. Meanwhile educators continue to develop online content and implement organizers for student use. The present research endeavours to broaden our understanding of the learning process by examining the effects of one type of learning aid, a navigable concept map, and the impact of learner control over navigation and awareness of one's location within the content. The preceding section outlined concerns related to existing research, which informed directions for the present study.

Research has suggested that organizers and concept maps in particular help learners to gain a sense of the content's big picture and aid self-regulated learning by requiring its use (Eckhardt et al., 2003). They may promote better studying behaviours and help with the cognitive processing of the content-to-be-studied. At times, studies have employed multiple organizers and more recently, navigable concept maps emerged as a possible learning tool for studying online. Although there is potential, our knowledge about their use is very limited. How learners engage with maps may provide insight into how learners draw connections between key concepts, gain a sense of the overall text structure, and check their understanding and review.

To address the varying types of organizers and means to navigate within one study, constraining the type of map and its functionality may result in a more precise understanding about map affordances on learning. Thus, the present study employs only one type of map. A structured overview of some sort appears to be better than no overview particularly for low prior knowledge or low ability learners (c.f. Hofman & van Oostendorp, 1999), and some research suggests that graphical maps are more beneficial than text formats because they make use of both the visual and verbal working memory stores (Vekiri, 2002). Therefore, a graphical map was selected for this study.

In the present study, learners gain a visual overview of the key concepts and their relationships; they can also see which topic they are currently studying, as well as concepts they have already visited. Previous research on graphic organizers and navigational maps have typically provided a means to navigate through the site via a map (c.f. Nilsson & Mayer, 2002; Potelle & Rouet, 2003), but few designs included a visual marker of visited pages on the map (c.f. Punambekar et al., 2003 for exceptions). Accordingly, organizers were generally static and did not provide any additional information to learners. Some studies provided the navigation function outside of the map while in others, how participants actually navigated within the environment is unclear. This variance in navigation may partly account for inconclusive results. Indicators of visited pages provide important information to help learners decide on where to go next. They reduce potential disorientation and the learners' need to monitor their pathways, thus enabling learners to focus more on the task, which may then result in better achievement (Khentout, Harous, Douidi & Djoudi, 2006). As well, in terms of self-regulation, learners may benefit from using the map to monitor their learning and for review since the map provides an overview of the key concepts and relationships.

Hypermedia environments, an online document with multiple media (text, sound, graphics and video) enable learners to direct their own learning in a more personally meaningful manner and to make decisions and experience its effects (Shader, 1999). Organizers are effective for learning and retention, but most of the research has been print-based which is often described as linear. Whereas hypertext provides more opportunities for connection-building and knowledge transfer and learner-control within hypertext is posited to facilitate better recall (Jacobsen & Sprio, 1995, cited in Shader).

All learners in the present study navigate to topics by clicking on a topic's node. The only treatment difference between the groups is whether learners control topic selection or follow an instructor or peer-determined sequence. By keeping the map type constant and examining different types of learner control, we may home in on the relationship between learner control and map use. The extent to which control over topic selection affects learning, whether learners benefit from selecting their own pathways or from an instructor-derived sequence, or if knowledge of one's location is important may be examined. Group differences in achievement would suggest advantages for a particular type of learner control, while examining learners' use of the map while studying may help to explain how these advantages occurred.

Understanding the process of studying is just as important if not more important than the outcome (Leu & Reinking, 1996), since changes in the former affect the latter. In particular, relationships between maps and self-regulation are currently underexplored. Therefore, another intention of this study is to examine the effects of a navigable concept map by employing a metacognitive framework to examine learners' use of the navigational display while studying. Maps are learning tools, which may affect learning outcomes; hence investigating their use while studying provides insights into the cognitive processes of studying online, particularly the level of awareness, monitoring, decision-making, and adjustments learners make.

Individual differences in interest, motivation and prior knowledge, and the learning task also influence the learning process and learning outcomes. For instance, Scheiter and Gerjets (2007) concluded that learner control seems to benefit learners with high prior knowledge and self-regulatory strategies, while navigational aids benefited low prior knowledge learners in McDonald and Stevenson's (1998) study. Learners with prior knowledge appear to be better at identifying their needs, and selecting and implementing appropriate information-processing strategies (Williams, 1996). The affordances of learning via hypertext and related map use may not have been evident because of the learning task and related assessment (Goldman, 1996). Therefore, in addition to acknowledging individual differences among learners, the present study also asks learners to apply what they have learned to a given scenario, which is a higher-order cognitive measure compared to a recall task.

In hopes of acquiring a more comprehensive picture of learners and of exploring the process of studying using maps, the present study uses multiple data sources and both qualitative and quantitative measures: learner characteristics, trace data, learners' rationales, and achievement measures. Self-report inventories have been the predominant measure for describing the studying experience. However, like Körner (2004) who used eye movement data to conclude a three-stage model to graph comprehension, this research uses eye movement data to extend knowledge about studying behaviours and cognitive processes associated with a navigable concept map in online learning. Hence, exploring the studying process using eye movement data is a unique contribution of the present study.

I designed this study purposefully to examine navigable concept map effects and the related online studying experience. It explores possibilities and provides trace data for future research to investigate the experiences of individual learners. Each layer potentially adds to a richer understanding and raises awareness of possible considerations. It is hoped that my approach to carefully examining one of the many available components of online content will influence future researchers by: (1) clarifying the relationship between learner characteristics and design factors, (2) advancing understandings of the applications of navigable concept maps and learner control effects, (3) exemplifying the importance to home in and clearly define the scope of their research, and (4) applying an alternate cognitive lens such as self-regulation and metacognition, which can provide important insights into the studying process. Understanding the process of learning online also has practical applications for content developers, the design of online environments, and support for students who study online, potentially enabling better designs and outcomes.

In sum, the present study aims to achieve three key goals: (1) to examine whether knowing one's location within the navigable concept map or control over topic sequence affects online studying and achievement, (2) to investigate the relationship between metacognitive awareness, self-regulated learning, individual differences, and studying and achievement, in relation to navigable concept map use; and, (3) to observe the studying process and learners' experiences using the map.

Dissertation Outline

Chapter I provided an overview of navigable concept map research, which is a conglomerate of several overlapping fields that emerged over time and partly in response to online learning. The chapter aimed to contextualize this study within existing research on learning tools and environments. In addition to identifying challenges with existing research on navigational maps and on how this study aims to address these, Chapter I outlined other intentions of this study.

The next chapter reviews the literature, outlines relevant studies and findings, and concludes with this study's research facets and questions. After gaining an overview of the field that influenced this study, in Chapter III readers acquire a detailed description of the study's method involving undergraduate learners at a mid-sized university. Chapter IV presents the results from the sixty-three participants and organizes the results by research question, level of specificity, and degree of exploration. Chapter V provides a discussion of the study's implications, constraints, and future research directions. Subsequently, the appendices contain the study's stimulus materials and data excerpts. Before moving too far ahead, let us return to an overview of existing literature that helped to inform the present research.

CHAPTER II: LITERATURE REVIEW

Learning with navigable concept maps is a relatively new field that has its roots in several areas. To appreciate its different functions requires a review of concept maps. The section includes a description of concept maps, theoretical foundations and related research on two central applications in learning for this study. A section on navigable concept maps follows describing its additional functionality as the means for navigation and the notion of learner control. Self-regulated learning is an alternate lens for examining map use, which differs from the more common explanations of cognitive load and dual coding. Adding to the complexity in navigable concept map research is its relationship with other variables and their influences. The chapter covers this relationship and comments on how the lack of data gathered *during* the learning process in current research is limiting, and how eye movement data may address this gap. The chapter ends with a description of the present study, its research facets, questions and hypotheses.

Concept Maps

Concept maps are diagrams representing key ideas and their relationships through node-link connections that educators may utilize in instructional settings as a learning aid. Intended to represent meaningful relationships between concepts, they visually depict some of the pathways to connect ideas or "a schematic summary" of the content (Novak & Gowin, 1984). A related term is knowledge maps, which are in essence a type of concept map however, they also include directional links and a common set of labeled links to connect ideas (O'Donnell, Dansereau, and Hall, 2002).

Nesbit and Adesope (2006) performed a meta-analysis to examine the research on concept maps and noted a substantial increase in research referring to concept, knowledge or node-link maps since 1985. Over 500 peer-reviewed articles, most published in the past decade, related to educational applications. At least three interrelated streams in concept map research have emerged. Researchers have investigated map effects when students construct or modify maps either individually or collaboratively (e.g. Novak, 1990 and colleagues) and the use of pre-defined concept maps while learning (e.g. Dansereau and colleagues). Both are primarily classroom-based applications, whereas I propose that a third line of research examines concept maps that are also navigational tools or markers of one's location within content in an online environment. In the latter two lines of research, researchers provide the learners with completed maps, rather than employing concept mapping as a learning activity.

Generally, concept map use has been associated with increased knowledge retention (Nesbit & Adesope, 2006). O'Donnell et al. (2002) in their literature review of knowledge maps also observed that some consistent findings have emerged since the early 1990's, namely that (1) learners recall more central ideas when learning from a map than from text, (2) map use benefited learners with low verbal ability or low prior knowledge the most, (3) the benefits of learning from maps are accentuated by active processing strategies and map design focusing on holistic patterns (based on Gestalt principles of organization), and (4) interacting collaboratively with knowledge maps stimulates more effective learning. Some commonly cited theoretical explanations address the ways in which concept maps may benefit learners.

Theoretical Explanations

Prior to describing concept map functions, this section outlines frequently cited interrelated cognitive models that have served as the theoretical explanations for much work in the field. As Vekiri (2002) remarked, these are based on information processing approaches to learning and, while assumptions may appear to be different, they are not necessarily contradictory.

Starting with Sweller's (1988) *Cognitive Load Theory,* mental processing occurs in the working memory system and the type of task and effort required make demands on one's limited working memory. Sweller, van Merriënboer and Paas (1998) have since described three types of cognitive load: intrinsic (load inherent in a task), extraneous (load resulting from irrelevant or unnecessary task features) and germane (load from relevant and important cognitive activities that help learners to achieve instructional goals). Many researchers have tried to explain how graphics work with text by examining concept maps (cf. Robinson, Katayama & Fan, 1996; Scott & Schwartz, 2007) or geographical maps (cf. Schreiber, Verdi, Patock-Peckham, Johnson & Kealy, 2002; Schwartz & Kulhavy, 1988, Verdi & Kulhavy, 2002) in terms of how they affect cognitive load. For example, maps benefit learners with less verbal ability or prior knowledge (cf. Chmielewski & Dansereau, 1998; O'Donnell, 1994) and maps may be attributed to reduced cognitive load through the limited number of words and the visual accessibility of the information macrostructure (O'Donnell et al., 2002). Furthermore, the connections between nodes in concept maps may reduce the cognitive effort normally needed to identify and associate concepts (Nesbit & Adesope, 2006). In sum, the graphical nature of concept maps may provide affordances to working memory, unavailable through text alone.

Related to reducing cognitive load, concept maps may aid in schema development. Long-term memory holds large amounts of information using *schemas*, foundational blocks of knowledge that are internally organized representations of concepts, events or objects (Fastrez, 2005). Schemas are created in working memory and vary in complexity and size. Schemas aid our limited working memory by amalgamating features and associations to the concept that, in turn, may be combined to form larger concept structures (Jonassen, 1986). Sweller (1990) asserted that instruction's prime goal is to aid the construction and automation of schema.

The visual format of concept maps may benefit a specific aspect of one's working memory. Paivio's (1986) *Dual Coding Model* describes two independent, yet interconnected and concurrent cognitive systems in working memory: verbal and visual. Advantages for the two modes suggest that (1) more elaborative encoding of the material to be learned and increased cues for retrieval occur, (2) the separate storage of verbal and visual information enables more information to be stored by dual coding, and (3) each store may be optimal for retaining certain types of information (e.g., verbal store for abstract information, visual store for diagrams) (Kirby, 1993). Dual coding may explain how graphical maps function and has served as the basis for numerous studies on learning with hypermedia (e.g. Mayer) examining how online content or multimedia materials can make use of these two processes to aid learning.

Maps provide visual information about the content's structure, while learners process text in the verbal store. Moreover, maps tend to chunk related concepts and in doing so graphically demonstrate the information's overall structure. The concepts and relations are coded into higher order links, which can increase information acquisition by freeing working memory capacity (Lohse, 1997). This idea applies to the use of navigational maps that provide a visual cue to learners on the content's structure without taking away from working memory where textual information can still reside in the verbal store. This may be affected by the structure of the map as well. O'Donnell et al. (2002) observed that a left-right knowledge map orientation could prompt learners to use a more verbal strategy, which results in superficial processing of the map's contents rather than benefiting from spatial processing. Learning from maps may activate spatial processing and help learners to identify important information and mine verbal and relational information.

Much research on the use of concept maps while learning has described its effect on cognition, particularly to reduce cognitive load and effectively employ two working memory processes. As described in a later section of this chapter, concept map use may be examined through another theoretical lens, however at this point, let us return to a review of how concept maps have been applied in learning based on the theory and models described in this section.

Applications for Learning

As mentioned earlier in this chapter, learners may participate in concept mapping or use pre-constructed maps. This section on concept map applications for learning focuses on the latter since the present study is premised on learning via pre-constructed maps outlining concepts and showing one's location within the map. The section reviews two main functions, concept maps as graphic overviews and as navigational aids.

As Graphic Organizers

Originally coined by Ausubel (1960), *advance organizers* (AO) resulted from his theory of meaningful learning: where learners actively associate new ideas with previous higher-level concepts. An AO is presented prior to learning to help learners to gain a sense of the overall content to be studied, to help recall prior knowledge, and to organize the new information (Vekiri, 2002). Ausubel had identified specific criteria defining an advance organizer but over time the term and its application has become more generalized resulting in varying types and methods of implementation. The original function of AOs was to link prior knowledge to new information (Ausubel, 1960), whereas Langan-Fox et al. (2006) describe contemporary AOs as information offering an organizational structure for interpreting new information. They are particularly useful for learners without prior knowledge. Currently, how and why AOs are effective and their effect in human-system interaction research remain unclear and its definition and criteria for creation, variant (Langan-Fox et al., 2006).

AOs may occur in text (linear) form or as an image. In image form they are called *graphic organizers* (GO), and have the added benefit of using their spatial format to denote relationships among concepts. Content developers need not restrict graphic organizers to appear only at the start of studying, but could provide learners with the opportunity to refer to them for the duration of their studying. Visual representation of GOs may take a variety of forms (e.g. tables), including a concept map form, which incorporates either labeled or unlabeled, and non-directional or directional links, or in the form of knowledge maps, a specific type of concept map with directional links and pre-defined symbols. Some explanations for the effectiveness of concept maps suggest similarities to outlines and lists, which also provide summaries of information (Nesbit & Adesope, 2006). Information that is highlighted or cued within text, otherwise known as *text signals* can take the form of an overview, headings, or summary. Generally, organizational signals help students to focus on important information (Kardash & Noel, 2000). Although Ausubel (1960) had identified specific criteria, inconsistencies in the definition and creation of advance organizers now exist (Langan-Fox et al., 2000) and Robinson (1998) has noted the same about graphic organizers.

Describing the effectiveness of graphic organizers can be challenging because there is no consistent operational definition for the term (Langan-Fox, et al., 2000) and no consensus among researchers on the most effective type of graphic organizer (Robinson, 1998). The term "graphic organizer" also has a more general meaning now, as an image that helps to organize high-level concepts and their relationships therefore no longer fitting specific criteria for graphic advance organizer (Langan-Fox; Robinson). Two common types of graphic organizers are linear and graphic maps. Perspectives vary on the efficacy of both and relative advantages of one over the other. Previous work on print-based graphical advance organizers or spatial metaphors has found inconsistent results (e.g. Tripp & Roby, 1990).

Research has also suggested that linear organizers help to provide the linear flow of information, but may obscure important relationships among concepts while graphic organizers provide a visual format to convey concept relations, promote elaborative processing and capitalize on dual coding (Robinson & Kiewra, 1995). Research on organizers in the form of lists or maps have consistently identified achievement benefits for learners when they had received an organizer compared to learners who did not. Although research has suggested stronger leanings toward benefits by graphical maps versus textual lists, it yielded mixed results on the effects of specific types of organizers: between lists, hierarchical maps and relational maps. As Langan-Fox et al., (2000) noted further research is needed to distinguish among the properties of subtypes of graphic organizers.

Most research on graphic organizers has investigated print materials, but over the last decade, research in online graphic organizers has emerged. Eveland et al. (2004) found that linear designs encouraged factual learning while nonlinear designs increased knowledge structure density: learning of the interconnectedness of the presented information. Chen and Rada's (1996) meta-analysis focused on three factors that may influence the use of hypertext: cognitive style and spatial ability of learners, complexity of tasks, and the structure of information organization and visualization of the structure. The meta-analysis on 23 experimental studies reported substantial differences among the experiments. The effect sizes for individual differences in cognition were not enough to claim significant differences. Performance of hypertext users tended to be better than non-hypertext users, while the researchers found the reverse for efficiency. Non-hypertext learners were more efficient in their tasks. The largest effect size was found for the complexity of tasks (r = .63). Most important to the present research is that graphical maps that visualized the content's layout had significant impact on the effectiveness of the hypertext system (r = .38). This suggests that the graphical maps aid students' learning from an online system and as Chen and Rada noted, implementing the map may narrow the gap between learners' individual differences; in this case spatial ability.

Two other subtypes of graphic organizers are *structured overviews* and *network maps*. Structured overviews have a spatial arrangement of concepts, listing the important concepts at the top, followed by subtypes underneath, and further subtypes thereafter (cf. Dee-Lucas & Larkin, 1995; Robinson & Kierwa, 1995). Unlabeled lines illustrate the hierarchical relations between concepts. The term "hierarchical" is not limited to top-down content organization; instead its defining feature is the portrayal of multiple levels of subordinate concepts with the intent to communicate superordinate-subordinate relations. The hierarchical nature aids learners with organizing the information and understanding the thematic structure of the text (Kools, van de Wiel, Ruiter, Crüts & Kok, 2006). Network maps also identify key concepts and subtypes, through an enclosed circle or box, but labeled links describe the interrelationships between concepts.

Dee-Lucas and Larkin (1995) investigated structured (hierarchical) and unstructured (list) overview effects on learning electronic text. The researchers defined the list overview as a menu-like text listing. Compared to traditional text, both types of overviews resulted in better recall and breadth of recall, but learners who lacked specific study goals demonstrated a more fragmented knowledge structure when using an unstructured overview. Learners found the structured overview easier to recall and use, and spent more time reviewing it when they lacked specific study goals. The researchers also found that the hierarchical map helped learners to remember the mental model they developed of the text structure. Brinkerhoff, Klein and Koroghlanian

(2001) echoed this finding and proposed that this resulted from the recall of higher-level nodes which prompted recall of lower-level nodes. They concluded that hypertext's efficiency might be enhanced by including a hierarchical organizer designed to reduce navigation and orientation problems, but noted that most research has been print-based, so transfer to hypertext environments remains unclear.

As Navigational Aids

The text structure provides the framework for the content studied by learners and is important regardless of the medium. However, online text differs from traditional text and the difference influences the process by which learners build representations of the content. In order to appreciate the differences and how concept maps may serve as navigational aids, a brief introduction to hypertext and hypermedia learning is required.

Online Affordances to Learning via Hypertext and Hypermedia

Hypertext is an electronic form of text presentation that supports non-linear linking of nodes or chunks of text (van Oostendorp & de Mul, 1996). A hypertext document provides branches or cross-references in the form of hyperlinks to information located elsewhere, enabling the content writer and reader to partly overcome the inherent linearity of print-based text. A *hyperlink*, commonly known as a *link*, is a reference or navigational element in a document connected to another section of the same document, another document or a specific section of another document, thereby providing the reader with the referred information. These links commonly occur as part of online content. Hypertext documents can be prepared and stored in advance (static) or created in response to user input (dynamic). Hypermedia environments are online environments containing *multimedia* (text, sound, graphics, and video) in one document (van Oostendorp & de Mul). For the purpose of this study, hypertext refers to static content, "link" is used instead of "hyperlink" and to bridge more common understanding and research terms, "online environment" is used synonymously with hypermedia (even though the former can be defined more broadly).

A potential advantage of hypermedia is its ability to organize and structure content. If designed to model knowledge structures clearly, hypermedia may model the knowledge structures of experts in a way that facilitates acquisition by learners (Dillon & Gabbard, 1998). Though there is a predefined structure that sets up the framework for learning, hypertext also allows the reader to access information in a non-linear manner and provides the opportunity for multiple entry points and more divergent approaches to reading, knowledge construction and learning. The nature of hypertext allows users to control the pace, order and selection of information hence enabling learners to decide on the sequence of information that is relevant to them, resulting in more meaningful learning (Jonassen, 1986). Although posited to allow for a flexible learning environment that best fits with learners' needs, the advantages of user control to enhance learning is mixed at best (Eveland, Cortese, Park & Dunwoody, 2004). More on learner control follows in a later section.

Goldman (1996) identified two challenges with hypertext use: The first is that learners process information in a linear order even though the hypertext environment provides opportunities for flexible navigation. Learners may not be skilled enough to monitor and regulate their reading behaviour in a non-linear environment. Consequently, they initially default to more familiar approaches and process information sequentially. Second, in addition to the disparity between learners' linear approaches to the task and affordances of hypertext, the ever-present recall task in research does not actually require more flexible learning approaches; ergo the task restricts demonstrating the potential of hypertext.

To capitalize on the affordances of hypertext, researchers such as Rouet and Tricot (1996) have emphasized the need for more attention to the cognitive analysis of information processing tasks. Much research examines the structure of text: the linguistic input rather than the strategies that learners employ to make sense of the text (Goldman, 1996). In Dillon and Gabbard's (1998) review, they observed that hypermedia use has not directly influenced learner comprehension but that its advantage may be mediated by other variables such as learner control. The presence of links affords decision-making and related interruptions to reading that can either improve the reading experience or make the learning process more complex (DeStefano & LeFevre, 2007). To use hypertext appropriately, users establish a task representation and task management strategy (Deimann & Keller, 2006). Furthermore, hypertext is not neutral, but affects both the process and outcome of cognition (Narciss, Proske, & Koerndle 2007). Experiencing the natural order of text may be important for learning, but is not sufficient for advanced learning and understanding. Instead, learners require ways to approach the text from multiple perspectives and to cross-connect segments and hypertext enables this cross-connection process (Narciss et al.). In order to make the best use of learning with hypertext, examining the learning process enables researchers to better understand whether learners make use of opportunities to explore the text and their associated rationales.

The Research

As described in the previous section, learning via hypertext or what I call "online" may provide both unique opportunities and challenges for learners as compared to print. For these potentially non-linear presentations, learners require specific strategies to know where they are, decide on where to go next and acquire a cognitive presentation of the information's structure. Concept maps may aid students not only by serving as a graphic organizer that illustrates the information macrostructure, key concepts and links, but also by showing one's pathway, current location and information not yet visited.

The complex data structure of online content may constrain the amount of information visible at once. Woods (1984) as cited by McDonald and Stevenson (1999) coined the term "keyhole phenomenon" which describes the situation were the content's overall scope and linking structure are not clear to viewers of a screen. This results in difficulties for learners in identifying their location within the networked content and in knowing how to progress to another point (Gerjets, Scheiter & Schuh, 2008). Additionally, studying online may result in cognitive overload because of the skills and attention necessary for learners to devote to navigation or orienting themselves (McDonald & Stevenson, 1998). This effort may occur at the expense of the processing necessary to achieve instructional goals (e.g. deep levels of processing) (Khentout et al., 2006; Scott & Schwartz, 2007).

To reduce disorientation and cognitive load, navigational aids in the form of overviews, outlines, hierarchies and maps may "support effective decision-making during navigation, allow for flexibility and learner control, while at the same time keep the learner from getting lost" (Puntambekar et al., 2003, p. 397). Most research on disorientation presents different navigational tools and structured overviews to address the problem (Scheiter & Gerjets, 2007). Organizers in the form of concept maps depicting the subject matter can assist learners with navigating and locating information in electronic texts (Dee-Lucas & Larkin, 1995).

Unlike advance organizers, these navigational map*s* are visible throughout the study session. They may reduce cognitive load by providing an explicit navigational structure of the content, helping learners to orient themselves. Through its visual depiction of the concepts, navigational maps prompt the processing of this information to take place in the visual working memory store, therefore freeing up the verbal store for the text. In other words, having both the graphical map and text makes concurrent use of memory stores. Without a map, learners require active attention to figure out the site's structure and to navigate through it. This may result in extraneous cognitive load. For example, when the navigational structure of a site was unavailable, learning outcomes were negatively affected (McDonald & Stevenson, 1998).

Similar to research on graphic organizers, research on navigational maps has generally found significant performance differences between learners who used a map and those who did not (Puntambekar et al., 2003). Yet maps are not a panacea as McDonald and Stevenson (1998) remarked that maps might foster "efficient navigation", but "may not be a prerequisite for effective learning" (p. 53). For that reason, it is important for a map to not only serve as a navigational tool but to illustrate the conceptual structure of the topic in order for the map to support both navigation and learning (Puntambekar et al., 2003). Failure to adequately present the conceptual structure of the domain could perhaps explain mixed results when comparing different types of navigational aids and their effects on learning.

To summarize, navigational maps may reduce cognitive load by providing an explicit navigational structure of the content, helping learners to orient themselves within the content (Scott & Schwartz, 2007). Through its visual depiction, navigational displays may make use of the visual working memory process and enable further processing of the actual content to take place in the verbal working memory. Related at a broader level is Shapiro's (2005) notion of the site map principle whereby learners benefit from appropriate site maps, which not only keep learners oriented within a website, but also complements learning goals. Nevertheless, performance on learning outcomes does not necessarily improve because of solely providing information about the content's navigational structure (Nilsson & Mayer, 2002).

Navigable Concept Maps

I use the term "navigable concept map" to refer to concept maps functioning as graphic organizers and navigational aids within online content.

As the Means for Navigation

The ability to navigate and observe one's pathway within hypertext commonly occurs through overviews, outlines or lists containing links and colour changes to the links indicate visited pages although researchers have questioned the method by which navigation occurs and its effectiveness. Rouet and Potelle (2005) explored several issues related to general navigational aids in hypertext: embedded links versus explicit menus, broad versus deep navigation, whether graphical representations or traditional list-based menus best convey informational structure, and how map layout might affect comprehension. Through their review, they concluded that the embedded links may be effective and preferred, but advised that the links should complement rather than replace a means for content representation. Citing numerous studies (e.g. Chiu & Wang, 2000; Larson & Czerwinski, 1998; Tung, Debreceny, Chan & Le, 2003), Rouet and Potelle reported that menu depth gave users a sense of complexity and be more challenging to navigate, and thus a "shallower" menu of two-levels may be optimal.

For a concept map to serve as the means for navigation, learners must interact with it in some way, such as by clicking on a concept to bring up the related text information. The map's presentation may also change to reflect the learner's pathway. Until recently, it was uncommon for maps to include dynamic functionality likely because of the complex, resource intensive design requirements and to ensure comparability with previous print-based research. Nilsson and Mayer's (2002) study is an example of this shift in functionality. They examined the performance and navigational strategy effects of graphic organizers that cued the text's structure. In their first experiment, they provided non-navigable maps, reasoning that previous research on maps and navigational performance used non-navigable maps. They also recognized that providing different means of navigation on top of variances in the information's structure could potentially confound their research. However in their second experiment, they modified their approach and employed navigable organizers for improve ecological validity and to reduce frustration by learners.

In Potelle and Rouet's (2003) study, they examined content represented in a text list, hierarchical, and networked formats. Learners selected topics within the maps to access the related text. Although the researchers found that the hierarchical map helped low knowledge learners with comprehension at the global level, it is not clear whether the results were due to the type of map, learners' ability to select the topics or a combination of both. Similarly, navigational differences between groups (clicking on unit titles for the overviews or using "next page", "previous page" and "finished" buttons for the traditional text) may have influenced Dee-Lucas and Larkin's (1995) finding that overviews produced better memory of topics and breadth of recall.

In Puntambekar et al.'s (2003) research, they developed a system that generated dynamic maps. Through CoMPASS, their hypertext system for middle school science learning, concept maps and text changed dynamically as students made decisions and navigated through the environment. More specifically, the maps incorporated a fish-eye lens by zooming in and out. Using data from student log files, they found that students used the provided navigational aids (index or map) which in turn, affected their navigational patterns. Students who used the map for navigational purposes demonstrated relevant transitions between concepts, visited related concepts and those that were in line with their learning goals. The researchers surmised that the concept maps might have provided students with conceptual support, which in turn, resulted in students focusing on relevant concepts and less need to transition between concepts.

Research to date on graphical overviews has reported mixed results with different types of overviews observed as being helpful in some tasks in some studies (e.g., Chen & Rada, 1996; de Jong & van der Hulst, 2002) while others reported no improvements in recall or navigation (e.g. Nilsson & Mayer, 2002). Although touted by other researchers to engage learners, Nilsson and Mayer suggested that the pre-established structure might reduce the likelihood that learners will build their own representations and consequently, learners may become less involved in learning. DeStefano and LeFevre (2007) concluded from their review of cognitive load in hypertext reading research that "complex graphical overviews did not reliability enable learning and navigation, whereas navigational support from restricted access and visible link types were helpful" (p. 1616). The possibility of interactions with other factors appears to be a reoccurring rationale for a lack of clarity about the benefits of navigational maps.

Another issue with studies on navigational maps is the potential for confounding the learner's level of control over instruction and the modality for presenting the content's structural information. This may account for some of the inconsistent results. Although maps may serve as navigational aids as described in the previous section, the research is unclear to whether or not (1) the map served as the means for selecting and moving within the content, (2) the map displayed one's navigational path (visited, current and not yet visited topics) and (3) the research design ensured that the process of navigating was consistent. A lack of attention to these details may flaw one's research, yet for the most part, these pieces of information appear to be lacking in the literature.

Specifically, aside from not being clear on how exactly learners navigate within online content, studies have employed organizers that vary in format such as lists (which are text-based) and hierarchical and relational graphics (e.g. Dee-Lucas & Larkin, 1995; Potelle & Rouet, 2003). As suggested by the dual coding model, the type of overview, whether it be text or a graphic affects where and how the organizer is processed in the verbal and visual cognitive processing systems which then in turn, influences cognitive load and learning. For example, through two studies, Robinson and Molina (2002) found that participants who used graphic organizers performed worse on a visual task, while users who studied the outlines performed worse on the auditory task. They concluded that learners encode graphic organizers visually and outlines in an auditory format. Therefore tasks that utilize the same working memory channel, end up competing with the learning aid and not capitalizing on the two memory stores. These findings were consistent with consistent with Robinson et al., (1996) and Robinson, Robinson and Katayama (1999). Since studies have included different overview formats (graphic and/or text), achievement differences may have influenced by the presentation format (text or image) and its processing or by the level of learner control.

The field of research on navigational maps is relatively young compared to research on print-based organizers. This newer body of research also requires researchers to consider map placement, navigation and learner control, which can further complicate matters. For example, the location of the map in relation to the text-to-be-studied may affect cognitive processing because the added step of having to select topics from an overview external to the text may interrupt text processing. On the other hand, the maps may make review and exploration easier by providing direct access to content or as Dee-Lucas and Larkin (1995) suggest, by making recall of the location of concepts and their connections easier to recall due to its spatial layout. In terms of navigation and learner control, it appears that the more navigational options learners have, the more confused they are (Gall & Hannafin, 1994). As Dillon and Gabbard (1998) concluded, researchers may manipulate control in many ways and the degree of control may vary and be difficult to measure. Therefore it is not surprising or unexpected that research on graphical navigational aids has been limited (e.g., Nilsson & Mayer, 2002; Potelle & Rouet, 2003; Puntambekar et al., 2003), particularly in the case where the graphic also serves as the navigational tool.

In summary, although the online environment embodies an information structure, linked nodes, and offers learners more control over their learning, research suggests many challenges and considerations. To achieve a more complete model of learning from hypertext research needs to consider learner characteristics (prior knowledge, motivation, interest, cognitive measures), which affect learner's strategies (DeStefano & LeFevre, 2007) and the appropriate level of learner control.

Learner Control

Synonymous with *interactivity,* the term learner control differs across research studies and may be operationalized as (1) sequencing, where learners decide on the order information is accessed, (2) content selection, determining which information to receive, (3) representation control, how content is displayed, and (4) pacing, the speed by which information is presented (Miller, 1997; Scheiter & Gerjets, 2007). Allowing students to exercise control over their learning environment may benefit learning. As students work at their own pace, they may be able to prevent cognitive overload and progressively build their understanding. Learner control in terms of topic selection and sequencing empowers learners to address their personal needs and preferences (Scheiter & Gerets). Autonomy in learner control may also increase learner motivation, while too little structure may result in frustration and decreased motivation (Hannafin, Hannafin, Hooper, Rieber and Kini, 2001).

Several arguments describe why learner control should be more effective than system-controlled learning environments (Scheiter & Gerjets, 2007). Two assumptions underlie learner control: (1) that learners know what is best for them during learning and (2) they are able to act accordingly (Jonassen, 1986). Researchers have enabled learners to decide on their learning process presuming that it would increase interest and motivation to learn since learners need to self-evaluate and take responsibility for directions for their own learning. A second argument suggests that learner control facilitates adaptation to preferences and cognitive needs. Deeper processing may occur as learners continuously identify the helpfulness of information to achieve their learning goals, construct mental representations, and integrate new information with prior knowledge and students may develop their own cognitive structures (Williams, 1996). Third, is the acquisition of self-regulatory skills whereby learner control may evolve students' skills at self-regulating their learning (Azevedo, 2005). Self-regulated learners manage their learning through different steps (task definition, goal setting and planning, regulation of cognition, and adaptation). Learner control and the related intrinsic feedback may foster these metaskills (Scheiter & Gerjets, 2007).

Many studies have examined learner controlled performance effects compared to system-controlled instruction. In the past, efforts focused on pacing whereby instruction remained somewhat uniform across the treatment groups (Jonassen, 1986), topic sequencing and the number of examples shown (c.f. Tennyson, 1980; Tennyson, Tennyson & Rothen, 1980). Current research on learner control has expanded to learner controlled sequencing, topic selection and information presentation and has yielded inconclusive results, which appear to vary depending on conditions such as "the nature of the decisions to be made" (Gall & Hannafin, 1994; p. 218), the learning task, levels of control, research setting, and subject domains. Dillon and Gabbard (1998) concluded that learner control seemed only to positively affect learning outcomes for high-ability learners. Scheiter and Gerjets (2007) also remarked that based on their review, learner control in online environments may be difficult to demonstrate due to usability problems (e.g. disorientation, cognitive overload), moderating learner characteristics (e.g. prior knowledge, self-regulatory skills), a lack of conceptual foundations and methodological flaws.

Reeves (1993) critiqued much of the learner control research on issues related to the definition of "learner control", lack of theoretical foundations, poor designs and data analysis. For example, many studies found no differences between learner controlled and system controlled instruction with researchers using the "no difference" result to justify either type of control or concluding that overall effects may not be detectable due to variance across learners and conditions (Williams, 1996).

Learner control effects depend on individual characteristics of the learner and explanations vary widely as well. In some cases, increased learner control appears to disadvantage learners with low abilities (Dillon & Gabbard, 1998). Williams (1996) noted that many research studies have advised against ad hoc offerings of a range of options to learners because they do not appear to improve overall learning. Lawless and Brown (1997) remarked that learning may benefit from control over one's instructional sequence, but unrestricted control and an absence of learning goals can suppress these effects. Other researchers postulate that learners lack skill or knowledge on using appropriate strategies in learner control situations. These learners can benefit from learner control with advisement that provides information about their previous assessment in reference to a specific level of mastery, which then helps learners to establish a better perception of their learning needs (Johansen & Tennyson, 1983).

Learner control in online environments can potentially be effective and detrimental to learning at the same time; these challenges are inherent to hypermedia. The cognitive demands of choice may affect the freedom to navigate to better address personal preferences while the openness of activities allows learners more flexibility to engage or disengage (Scheiter & Gerjets, 2007).

Map Use through a Self-regulated Learning Lens

As suggested in the previous paragraph, depending on the individual learner and the map, navigational maps may increase or decrease cognitive load. Although many studies relate map effects to cognitive load, a challenge to these arguments is that cognitive load is difficult to observe. By operationally defining certain study behaviours, traces of self-regulated learning however, may be observed as exemplified by Perry and Winne (2006), Winne et al., (2006), and Chu (1999).

Requiring both an awareness of others' expectations and self-direction, studying may be characterized by a *self-regulated learning* (SRL) model comprising four stages: (1) task definition, (2) goal setting and planning, (3) enactment, and (4) adaptation (Winne & Hadwin, 1998). First, learners identify the purpose of the activity or the instructional goals, which become standards by which the activity will be evaluated. Second, learners decide on personal goals to direct their learning. These constitute the criteria by which learners monitor their studying (Winne & Hadwin). These goals may be simple or complex and may be altered when personal and perceived task standards differ. A plan is created to advance toward the goals. As planned strategies and tactics are deployed, the products of these operations prompt self-evaluation. This monitoring may in turn result in changes to the original plan. The final stage of studying may or may not occur depending on the learner. When present, it consists of adaptive decision-making where learners consider how their actions worked in all stages of studying and the adjustments that were made or not made to facilitate their learning.

At the most basic level, self-regulation occurs when students adapt to their changing environments (Zimmerman, 1995). Main components of self-regulated learning (SRL) include metacognition, motivation and strategic action (Winne, Jamieson-Noel, & Muis, 2002). Based on cognition, SRL requires inference and operational definitions by researchers since they cannot directly inspect cognitive events and characteristics. SRL includes deliberate regulatory actions from the past, which learners have automated, can examine and adapt as they work towards a goal. The authors also note that SRL is examinable through different activities: metacognitive monitoring, whereby learners consider the task and their work to date in light of standards and goals; and metacognitive control, the cognitive component that explains what learners do because of monitoring. If-then representations tie monitoring to control, and form a tactic, while learners construct a strategy from a set of tactics.

Generally, educators presume that learners actively attend to the given material, reflect upon its importance, determine its fit with prior knowledge and build linkages with prior knowledge. Learners are active participants in their own learning process and may be metacognitively aware of their learning, which then influences their motivation and behaviour while learning. Being aware of gaps in their understanding and knowledge about a topic, learners actively engage in learning through the process of studying. They identify and select new information and process how it fits with their existing knowledge in order to build their further understanding of the topic. Metacognition is the awareness and ability to reflect upon, understand and adapt one's learning and is a vital element of self-regulated learning (Paris, 2003).

More specifically, two metacognitive factors influence decisions within SRL: *knowledge of cognition* and *regulation of cognition*. The former consists of subprocesses that aid reflection: perceptions about one's strengths and weaknesses in learning, and awareness of strategy use and the effectiveness of one's learning under certain conditions. The latter entails subprocesses related to the control of learning: planning, information management strategies, monitoring and debugging (Hill & Hannafin, 1997; Schraw & Dennison, 1994) and represents the aforementioned SRL model. Metacognitive knowledge will significantly mediate success in most learning situations (Shraw, 1998). Metacognition is akin to self-monitoring, student's awareness of their performance or comprehension and self-monitoring has a positive influence on achievement (Kauffman, 2004). Learners with weak metacognitive knowledge and skills may be limited in identifying their learning needs, evaluating, and revising their learning strategies (Hill & Hannafin, 1997). To construct meaning from their navigating, learners must regulate their cognitive strategies, thus metacognitive skills are particularly important in hypermedia learning (Puntambekar & Stylianou, 2005; Schwartz et al., 2004).

Schraw and Dennison (1994) developed the Metacognitive Awareness Inventory (MAI) based on the premise that metacognitive awareness affects learners' approaches to learning and performance. The MAI aimed to address the challenge of identifying metacognitively aware learners quickly and reliably (Schraw & Dennison, 1994) so that educators may provide more appropriate learning designs. Recently studies have begun to employ this inventory as a predictor of performance in research on online environments (e.g. Hartley & Bendixen, 2003; Kaufmann, 2004). As with any instrument, there are critiques however, few instruments exist to gauge metacognition. For the purposes of this study, the MAI's identification of categories based on statistical analyses is beneficial. Further, its use by both teachers and in some related research makes the MAI valuable in both its familiarity and as a basis for comparison and consistence with other research; I chose to use the MAI in my research to identify learners' level of metacognition prior to treatment since it would likely influence studying behaviours and outcomes.

Successful self-regulated learners are alert to the appropriate use of learning strategies and their effectiveness (Lan, 1996; Zimmerman, 1998) because of internal feedback created through the monitoring process (Butler & Winne, 1995). Nevertheless, monitoring even by skilled adults is frequently far from optimal and more likely to occur during assessment than studying (Pressley & Ghatala, 1990). Failures to self-regulate may include weaknesses in self-reflection and understanding about one's ability and strategies for learning, ineffective planning or monitoring, and inappropriate strategy selection and enactment (Winne 1995, 1997; Zimmerman, 2001). Moreover, possessing metacognitive knowledge and skill (knowledge and regulation of cognition), does not in itself guarantee that learners engage in self-regulating activities such as monitoring (Pintrich, 1995; Zimmerman, 1995).

The role of metacognitive skill in learning is complex. Research has reported positive relationships between learning and the engagement of learners' metacognitive skills and attributed to learners being able to plan, sequence, and monitor their learning to improve their performance (Schraw & Dennison, 1994). Responsibility for and control of learning are related to the effectiveness of students' self-regulated learning (Pintrich, 1995). However, the effects of metacognition are not always positive, but theorized to be dependent upon specific factors and learning scenarios (Paris, 2003). Students can vary in the degree to which they self-regulate and their selection of strategies for learning may or may not align with the learning task. For example, a learner may determine that he or she has little or no understanding of a topic and may proceed with a, "learning it all" approach. This may result in focusing on textual details and missing the overarching picture and relationships among key concepts.

Interactions with instructional materials provide learners with the opportunity to self-regulate although metacognitive skills mediate the effective use of multimedia learning aids by learners (Eckhardt et al. 2003). Purposefully designed materials may prompt or support SRL (Zimmerman, 2001). One example is the use of navigable concept maps, which may support learners' active and flexible construction of mental representations. Consequently, learners must take more responsibility and actively structure and organize the information whereas with conventional text this responsibility has been borne primarily by content authors and designers (Goldman, 1996). Although learners actively organize and structure information in both print and online mediums, they require more information seeking decisions when studying online (Eckhardt et al.). Thus, acquisition of appropriate learning skills is critical. Furthermore, unlike text content, concept maps have no standard reading order. The act of deciding on a node for viewing (or topic selection during navigation) may foster deeper learning strategies and metacognitive engagement than the surface strategy of repeated reading that can occur with text (Nesbit & Adesope, 2006).

Linderholm and van den Broek (2002) (as cited by DeStefano & LeFevre, 2007) found relationships between strategy use and individual differences in working memory. Specifically, learners with a higher working memory capacity reflected more and used metacognitive comments, while lower capacity students employed less demanding strategies such as repeating statements verbatim. Although cognitive load and dual coding merit consideration, learners' metacognitive ability when using maps is also important, as noted in Shapiro (2005) in her review of a broad range of learning outcome studies. Despite its importance, only more recently have studies concentrated on the relationship between self-regulation and online learning: the environment itself placing high demands on learners in terms of their SRL because of the openness of the environment. Several researchers have suggested that learners with self-regulatory skills benefit more from learning online than those who have weaker skills (Azevedo, 2005; Hartley & Bendixen, 2003). For instance, learners with different levels of self-regulated learning responded disparately to learner versus system controls; specifically, poorer performance was associated with lower SRL (Young, 1996), although the environment and the extent to which self-regulation are needed for the task also have an effect (Scheiter & Gerjets, 2007).

Another example of more recent research on navigable map use employing a metacognitive lens is Scott and Schwartz's (2007) research based on previous work that reported that a learner's level of metacognition significantly predicted information recall when a site map was complex. They designed their study to determine metacognitive factors related to the use of different navigational maps. High metacognitive learners were better able to make meaning of the information and understood more from the website. Employing a metacognitive measure to identify learners' level of metacognition and the use of both recall (lower cognitive level) and problem-solving (higher cognitive level) tasks, were unique contributions of their study. The researchers concluded that map use can result in significantly more cognitive load, but this is not necessarily negative, depending on whether the load is germane or extraneous. Germane cognitive load correlates to the task, how learners handle the load depends partly on one's level of metacognition, and learning may benefit from engagement of metacognitive skills (Scott & Schwartz). The learners' metacognitive skill may mediate the effectiveness of learning aids such as navigable concept maps (Eckhardt et al., 2003).

Building on the advantages of concept maps and the notion of self-regulated learning, I propose that navigable concept maps may support self-regulated learning in a number of ways. First, prior to studying, review of the map may help learners with planning. Second, while studying, learners may use the map to monitor their comprehension, pace their studying, build a cognitive framework and connect the current concept with others. Third, at the end of a study session, the map could serve as a review tool for learners to examine the content's macrostructure one last time and consider how the concepts they had just studied fit within the larger context. Throughout the entire studying process, the map may also serve as the direct means for navigation and allowing learners to engage with the content and make decisions on where to go, if applicable. Obtaining data on actual studying behaviours is a first step for researchers to identify how learners may use navigable concept map for self-regulation. As Shapiro (2005) proposed, much more research is needed to answer questions such as how site maps are really used and how the nature of learner's goals, knowledge, and experience (abilities, including metacognitive) affect map use and further, to better understand what is an appropriate map.

Relationships with Other Variables

The functions afforded by graphic organizers, concept maps and navigational aids an online environment provide the foundation for navigable concept maps. Theoretical explanations have broadened to include other important processes while learning, namely self-regulation. Researchers have reported inconsistent findings and remarked how further research and consideration of other critical variables are required to understand map use. Interest, prior knowledge, motivation and the learning task are interrelated factors that influence the learning process and outcomes of many studies to date.

Interest, Prior Knowledge and Motivation

Personal agency, motivational, social and environmental factors may influence metacognitive knowledge and skill. For instance, students who are skilled in self-regulating may experience decreased self-regulation due to a lack of interest in the topic or fatigue and environmental effects, such as task demands that overwhelm rather than stimulate the learner (Alexander, 1995). Wade (2001) noted that theories of interest assume that interest results from an individual's interaction with his environment. Theories have focused on environmental factors that foster interest in individuals (situational interest) or on individual characteristics (individual or personal interest). Situational interest occurs during an activity, is temporary and arises from the learning environment (Schraw, Flowerday & Lehman, 2001) while individual interest develops over time, is relatively stable, topic or activity-specific and related to personal relevance, high value, increased knowledge and intrinsic motivation. (Hidi, 2001; Wade). Together, these two types of interest assist cognitive functioning and learning (Hidi).

Research has linked higher levels of interest with deeper processing, increased effort, feelings of enjoyment, more attention and better learning (Wade, 2001). In addition to increases in performance scores, interest may affect the quality of learning. Schiele and Krapp (1996) as cited in Hidi (2001) discovered a relationship between interest and deep-comprehension questions, recall, and better organization of knowledge structures. Interest can motivate learners to process the content more. For these reasons interests warrants attention by content developers and consideration on how to instil interest in their materials. However, an attempt to foster interest may result in negative or positive effects. The inclusion of interesting anecdotes or details that are not essential (seductive details) has been found to interfere with learning important information; some learners have difficulty identifying important information or do not grasp important information as the author had intended and the additional information may further complicate learning. As a result, Wade emphasized making *important* information interesting. Based on findings from Wade, Buxton and Kelly's (1999) work, Wade identified several conclusions and recommendations for content development. First, some topics may create emotional interest (e.g. danger, power, death), but most interesting information was related to individual and cognitive interests. For example, the information may provide answers to questions that are on the learners' minds, consist of examples they are able to relate to, be generally comprehensible and coherent, include explanations and background knowledge and be devoid of difficult vocabulary. Interesting information is likely valued and as a result, remembered.

Building on Wade's (2001) notion of fostering interest through personal relevance, information that is meaningful to a learner and for that reason attended to, depend on the learner's level of expertise (Kalyuga, Ayres, Chandler, & Sweller, 2003). In terms of map use, researchers have found hierarchical maps to benefit low prior knowledge students, but not high prior knowledge students (cf. DeStefano & LeFevre, 2007; McDonald & Stevenson, 1998; Potelle & Rouet, 2003). This suggests that the hierarchical format and image representing the overall text structure, helped learners with less domain knowledge to integrate new information into their mental representation of the given topic (Scheiter & Gerjets, 2007). The support and pre-structured paths may have reduced cognitive load, though these effects vary on the task and domain.

McDonald and Stevenson (1998) demonstrated the advantages of navigational aids for low prior-knowledge learners. In their study, learners received text with a navigational aid (concept map or list) or without an aid (only hypertext nodes and links). The aids resulted in improved comprehension, but only for learners with low-prior knowledge. It seems that while maps aid less knowledgeable learners, they have negative or neutral effect at best for knowledgeable learners. These learners already have knowledge structures in place, thus the map may conflict with existing schemas or learners perceived the tool to be too simplistic to be of value.

Some research has also investigated the effects of different types of maps in relation to prior knowledge. Shapiro (1999) found that low prior knowledge learners benefited from using an interactive hierarchical map and provided better answers than learners who did not receive a map. Positive results for low prior knowledge users of hierarchical compared to networked maps (cf. Hofman & van Oostendorp, 1999; Potelle & Rouet, 2003) suggest that the complexity of networked maps (where there are multiple semantic links) may impede learners from constructing a mental model of the content and may distract learners from processing appropriately. The maps neither negatively nor positively affected high prior knowledge learners. Potelle and Rouet observed that high prior knowledge participants learned comparably regardless of the type of map. Whereas for low prior knowledge learners, it appears that content representation needs to be easy to understand and clear, yet demonstrative of global relationships among the topics (Rouet & Potelle) and hierarchical concept maps appear to best meet these needs.

Furthermore, prior knowledge also governs strategy use. Whether a task is complex or simple depends only partly on the structure of the tasks and depends on the learner's expertise in a domain (Kalyuga, Chandler, & Sweller, 2001). In terms of learner control and its effects on learning, the choices learners make may not be faulty per se, but rather a result of their perceptions of the problem based on their prior knowledge. This prior-knowledge hypothesis suggests that learners may need some foundational knowledge to benefit from learner control and make judicious choices (Williams, 1996). Researchers have found interactions between metacognitive level and prior knowledge as learners engage in self-monitoring to determine their level of knowledge. Two studies (by Dillon, 1991 and Lawless & Kulikowich, 1994) reported by Lawless and Brown (1997) found that learners with higher prior knowledge had fewer problems with navigating the content, could attend to areas of interest and learned more as a result. The researchers attributed greater metacognitive awareness by the high prior knowledge students to the findings and presumed that learners monitored the content's structure based on their previous knowledge, identified new links and information and related them back to the foundational knowledge that they already had.

Alexander and Jetton (2003) remarked that having foundational knowledge and domain-specific strategies may not be sufficient for learning, but rather motivation or interest can also play key roles and impel students to dig deeper into learning.

Increased recognition of the influence of interest and motivation on achievement has resulted in several research studies and the identification of numerous constructs. For example, Schiefele and colleagues reported that 10% of the variance in general and short-term learning achievement tasks is associated with differences in motivational factors, yet researchers know little about how the effect operates (Ainley & Hidi, 2002). Williams (1996) concluded that students' level of motivation was an important predictor of student success under learner control. A learner's level of motivation to use strategies and regulate cognition and the effort they are willing to expend affects self-regulation and likely the associated learning outcome (Pintrich & DeGroot, 1990).

Finally, interest influences motivation and persistence, which in turn may affect achievement. Ainley and Hidi (2002) conducted several research studies examining the relationship between interest and learning. They found that topic interest affected students' affective responses, which then contributed to the extent to which students persisted on each test and that persistence was related to test scores; thus, interest had an indirect effect on achievement.

Individual differences play a key role in learning. The more prior knowledge, personal interest and related motivation a learner has, the more effective learners are in distinguishing pertinent and important information (Alexander & Jetton, 2003). In sum, research on navigable concept maps need to attend to not only the multiple functions of the concept map, but also recognize the interrelated influences of interest, prior knowledge and motivation on learner control, map use and thus, learning and achievement.

The Learning Task

In addition to the affordances of different types of maps and influences of learner characteristics such as metacognitive skill and prior knowledge, another important variable to consider in navigable map research is the learner's task, which consequently affects their studying and the mental representations learners construct. Learned information is stored as chunks or informational units, which are linked together to form macrostructures or larger chunks that help to organize and reduce complex information

(Schwartz & Kulhavy, 1988). Kintch's (1988) *Construction Integration Model* suggests that for recall tasks (low cognitive level task where the text explicitly mentions the answers) learners can achieve good performance from a good textbase representation created from its semantic content and that mirrors the text's organization. Concept maps may serve this purpose.

For higher-level tasks, such as inference and application where answers are implicit within the text, learners require integrating knowledge with multiple concepts and prior knowledge, which occurs in situation representations (Goldman, 2000; Potelle & Rouet, 2003). Many of the studies on graphical maps have relied solely on recall measures and have reported mixed results or no effects while research on text signals and advance organizers (primarily print) have more rigorously examined effects on different achievement measures. Failure to find detectable effects in navigable or graphical map research may be a result of the type of achievement measure used in the study. In order for learners to capitalize on the cross-connections afforded by hypertext environments, thereby forming a situation model and integrating knowledge, higher-level cognitive tasks are required (Goldman) and the recall measures employed to date may have been inappropriate. The field would benefit from more research on higher-level cognitive tasks (Goldman).

Capturing the Learning Process

Current research also appears to use little observational data on how learners actually use graphical or navigational maps. Instead, researchers acquire data through indirect measures such as think-aloud, achievement scores, or post-studying self-reports. Approaches to discover the underlying cognitive processes at work in studying have unique challenges and limitations (Willis, 2004): Learners, who actively engage with content while learning, may not be aware of their actual process, let alone be able to articulate this process during or after studying or through self-reports. A think-aloud protocol may bring the process and rationale for interacting with text structures and cues to the forefront, but has its own challenges. Participants may not be comfortable with verbalising their processes, this additional meta-level processing may conflict with actual studying, may be more appropriate for a less cognitively demanding task such as reading, and lastly, when combined with the task of studying and relatively new hypertext environment, this may prove to be overly demanding for students. Instead, I decided to administer an online post-studying experience questionnaire to gather data about the studying experience and the navigable concept map, and to gather eye movement data which provides a relatively unobtrusive means for obtaining data about learners attention to specific content while studying, namely the navigable concept map.

The main advantage of eye movement research is that it studies recordable and measurable behaviour. Assuming that eye movements reliably correlate with sequential centring of attention, researchers may observe eye movement data to understand the process of thinking (Josephson, 2005). Eye movement research embraces three assumptions: (1) Eyes fixate on information that is currently being processed, (2) fixation time is directly proportionate to processing time and (3) eye-fixation sequence corresponds to the order of processing (Josephson).

Eye movement research predominantly occurs in cognitive psychology and physiology (Josephson, 2005). Eye movement research employs eye-tracking equipment and software and assumes that there is a stable configuration by the brain, which produces a mental image (Josephson). This image is in constant motion, contrary to beliefs that eyes glide smoothly when viewing or reading. Detailed visual information is obtained through the fovea, a small central area of the retina. Through the fovea, one can observe a person's saccades and *fixations*. Saccades are rapid movements that indicate when the eye's focus changes to a new location. They occupy approximately 10% of the total time spent viewing information, and rarely do the eyes move beyond a 15-degree visual angle. Saccades separate fixations (Josephson; Rayner, Chace, Slattery, & Ashby, 2006). Fixations or fixation points are necessary to process details and indicate where a person is directing his or her attention. They occur when a person looks at a fixed point and they last between 200-500 *ms*. During a fixation, a person processes only one to five degrees of the visual angle of view because he selects only a small area of available visual information at any time.

Fisher, Karsh, Brietenback and Barnette (1983) reviewed fifty years of research and surmised three widely accepted propositions: (1) High semantic or high visual information leads to the accumulation of fixations in these locations, (2) fixations are responsible for perception; they are a reflection of the individual's cognitive strategy and, (3) fixation sequence enables the encoding, storing, and subsequently reconstruction of the images (cited by Josephson, 2005). Over these fifty years, research has recorded three main kinds of information (Rayner, Juhasz, & Pollatsek, 2005). First is *fixation frequency*: the total number of fixations a person makes on an area of the visual field. Second is *fixation duration*: a related measure to fixation frequency where the sum of the length of individual fixations in milliseconds is recorded when one looks at a specific visual area. Generally, the range for fixation duration is 200-300 *ms*. lastly, is the *fixation sequence*: the hierarchical mapping that records the order visual information is scanned. The order individual elements were viewed denotes the *scanpath*.

A recent study (Rayner et al., 2006), demonstrated that processing times and the number of fixations increased with difficult text and when presented with inconsistencies within the text, readers' fixation on the region where the inconsistency occurred increased. In both studies, they also found that difficult or inconsistent text increased the probability that readers would make a regressive eye movement. Although researchers have found correlations between eye movement patterns and reading skills, eye movements rarely cause reading problems but rather indicate difficulties in encoding words and understanding text by less skilled readers (Rayner et al.). Higher order comprehension processes seem to affect eye movements during sentence processing. Specifically, when skilled readers encounter ambiguity, higher order comprehension processes supersede default processing, resulting in longer fixations or regressions back to previously read text (Rayner et al.).

The main advantage of eye movement research is that attentional behaviour is now recordable and measurable; researchers may observe and analyze eye movements to understand the process of thinking (Rayner et al., 2006). As well, monitoring eye movements during reading can provide valuable information about moment-to-moment comprehension processes (Rayner, 1998). More commonly used in reading comprehension research and more recently, online commerce and web search behaviours, the use of eye movement data is sparse in research related to comprehension of graphics (e.g. Körner, 2004). Few studies have examined on-line strategies for studying texts, let alone the utility of navigational maps on metacognitive monitoring while studying online. Eye movement data can also enable us to "see" patterns in studying behaviour. Researchers may then examine the data in conjunction with students' reported metacognition monitoring and reported reasons for attending to and using the navigational map during their studying, thereby providing researchers with a more comprehensive picture of learners' metacognitive monitoring and navigational map use while studying.

The Present Study

One of the aims of this study is to examine navigable concept map effects on online learning: while holding the type of graphical organizer constant, to determine whether knowledge of one's location within the content or control over topic sequence affects online studying and achievement on two types of test questions. Research on graphic navigational aids has not sufficiently distinguished whether positive learning effects were due to (1) knowing one's location with online content (e.g. the issue of being lost in cyberspace) or (2) the freedom to select one's studying path (e.g. learner control over sequence). This study attempts to separate these two possibilities through experimental control. Specifically, the graphical navigational map always resides above the text. It presents the key concepts, their relationship to each other and clearly indicates the active, previously viewed and topics not yet viewed. In other words, learners always know where they are within the content. Where the variance lies is the level of control learners have over their studying path. To investigate learner control over sequencing effects, the experiment's design constrained learners' ability to navigate by ensuring that they studied all topics and by inhibiting learners from to going back and reviewing previously viewed topics.

As presented earlier in the dissertation, this study inquires whether learner control over topic selection has a positive effect on studying and consequently on achievement or alternately compared to merely knowing one's location within the content. This would suggest that the decision-making process of which topic to study next prompts learner's active engagement with the content and an awareness of connections and regulation of one's learning.

The study also investigates map use in self-regulated learning, the relationship between prior knowledge, knowledge of cognition and regulation of cognition as captured by the Metacognitive Awareness Inventory (MAI), motivation, interest, and map utility on studying and achievement. Further endeavours include depicting a more comprehensive picture of learners for future research, seeking to better understand cognitive processes and studying behaviour related to map use and making recommendations about instructional design directions. In sum, I tried to present a multifaceted interpretation of online learning via navigable concept map use by learners.

To accomplish these goals, the study captures both qualitative and qualitative data and at broad and detailed levels where possible. It explores learners' studying behaviour using eye-tracking technology, tentatively examines the relationship between eye movements, studying, and achievement and elicits feedback on the learner's experience. Through qualitative data, the study aims to create a detailed profile of learners, examining not only what they did and how, but also why.

What is "map use"?

I posit that the navigable concept map can serve five functions depending on the studying phase. Prior to studying, a graphic advance organizer provides a visual framework for new knowledge and prepares learners to draw upon prior knowledge if applicable. While the learner is studying: The map operates as a *navigational tool* revealing the available topics and connections between them and enabling learners to click on topics to access associated content and, in the case of the free group (learner control), it is a means for self-directed topic selection. A related role using the map as a *pathway indicator*, which shows the learner where they have visited, their current location and topics not yet visited. The concept map is *material-to-be-learned* in itself, illustrating the concepts and their connections. Finally, while studying and at the end of the session, learners may use the map as a *means to monitor and review* their learning.

Research Facets, Questions and Hypotheses

Does learner control over topic sequence affect the online learning experience and performance of students? What is the relationship between perceived metacognitive awareness, self-regulated learning, individual differences, and studying and achievement, in relation to navigable concept map use? What observations may be made about the studying process and learners' experiences using the map? The present study contains multiple facets, starting with map effects on studying and achievement; followed by examining prediction models for self-ratings of learning, recall and application measures; using eye movement data to observe map use while studying; and learners reported experiences about their studying and map use. To examine learner control effects, I created three treatment groups, described in *Table 1*.

Table 1: Treatment groups description.

Treatment	ID numbers	Description
Free	100 series	Learner control; controlled the viewing order of the topics.
Clockwise	200 series	Program control, instructionally sequenced; started in the centre and proceeded through the topics clockwise.
Yoked	300 series	Program control, peer-sequenced; followed a predetermined topic viewing order set by a peer, an associated free participant. For example, participant #303 viewed the topics in the order that #103 freely selected earlier.

Prior to describing further questions and hypotheses, *Table 2* identifies the key individual differences, process and outcome variables derived from the data collected for this study. These variables are employed in the analyses reported in the Results chapter, which also contains results derived from qualitative data.

Table 2: Key individual differences, process and outcome variables.

Individual Differences	Process	Outcome
• Age • GPA • Sex • Credits • Major • Age first started using a computer • Internet use • Number of courses with online study materials • Self-report on learning with online vs. print materials • Prior knowledge score *(sum of 6 items below)* - Score on gene question - Score on hybrid question - Score on technique question - Score on food question - Score on technology question - Score on regulations question • MAI knowledge of cognition *(sum of the 3 subscales below)* - Declarative knowledge *(sum of 8 items)* - Procedural knowledge *(sum of 4 items)* - Conditional knowledge *(sum of 5 items)* • MAI regulation of cognition *(sum of the 5 subscales below)* - Planning *(sum of 7 items)* - Information management strategies *(sum of 10 items)* - Monitoring *(sum of 7 items)* - Debugging *(sum of 5 items)* - Monitoring *(sum of 6 items)* • Condition group	• Self-ratings on learning *(for each of the 17 topics)* • Self-ratings on learning (average) • Study topic order • Time on each topic • Total time studying the map area • Total time studying the text area • Total time spent studying • Total time not fixated • Fixation activity on start page • Fixation activity on first 1/3 • Fixation activity on second 1/3 • Fixation activity on last 1/3 • Fixation activity on final page • Number of fixations on the map area *(for start page & each of the 17 topics)* • Number of fixations on the text area *(for start page & each of the 17 topics)* • Total number fixations on the map area • Total number of fixations on the text area • Total number of fixations during the study period • Number of distinct times the map area was observed *(for start & each topic)* • Number of distinct times the text area was observed *(for start & each topic)* • Total number of distinct times the map area was observed • Total number of distinct times the text area was observed • Average fixation duration *(for each of the 17 pages)* • Overall average fixation duration	• Recall score • Application score • Map utility rating • Self-reported interest • Self-reported motivation

Navigable Concept Map Effects

1. Do differences in learner control over topic selection contribute to detectable differences in self-ratings of learning for the treatment groups: (1) learners who control the order in which they study the topics (*free*), (2) learners who are guided in an instructionally rationalized sequence (*clockwise*), and (3) learners who are directed in a peer-rationalized sequence (*free*)? The treatment influences the studying experience, which then affects learners' perceptions of their learning and indirectly, their achievement.

   H_1: Learners in the *yoked* group, who lack control over topic selection and experience peer-rationalized sequences, will self-rate their learning more negatively than learners in the *free* group who had full control over topic selection. Learners who lack control and for whom the logic of topic navigation may not be clear will find the learning experience possibly more confusing or less meaningful. Learners who control their study sequence may be expected to provide more positive self-ratings.

   H_0: Learners who have control over the sequence of the study topics (*free*) and learners who have a peer-predetermined sequence (*clockwise & yoked*) will not significantly differ in their self-ratings of learning.

2. Are there any differences in recall and application scores between (1) learners who control the order in which they study the topics (*free*), (2) learners who are guided in an instructionally rationalized sequence (*clockwise*), and (3) learners who are directed in a peer-rationalized sequence (*yoked*)?

   H_1: Learners who control the topic sequence (*free*) will perform better on the achievement measures compared to learners who were directed in a discernable pattern (*clockwise*) or learners guided by a peer's selection (*yoked*). Topic selection enables learners to think about and make decisions on where to navigate through which may assist with developing connections between topics and learning the subject matter in a personally meaningful manner.

H_2: Learners who are guided through the content in an instructionally rationalized order (*clockwise*) will score higher than the other two groups. Learners with limited prior knowledge require more support; thus, an instructionally rationalized sequence may provide some predictability and a logical structure to the topic order. The pre-determined sequence frees learners from expending cognitive effort on topic selection. Instead, this effort may be directed to learning the content. A peer-rationalized sequence may not provide the same level of rationalized sequencing for the learner, which could then have negative effects on learning.

H_0: There will be no differences between the three groups on the achievement measures.

Considering Individual Differences

To what extent do prior knowledge, metacognitive awareness, personal attributes (interest and motivation), and learner control contribute to learners' average (1) self-rating of their learning over the study period, (2) learners' scores on the recall measure and (3) scores on the application measure? Researchers have frequently reported the effects of individual differences on learning. Which ones may predict learning outcomes in this study?

Exploring How Learners Study

The map is the central focus of this study and I designed it as a key component for studying. What are the general trends in how learners use the map and are there differences across the treatment groups?

H_1: Learners who do not control the topic sequence, but can see a general pattern to the order (*clockwise* group); will spend less time examining the navigational map, compared to the other two groups. Since learners will navigate in a pre-determined clockwise pattern and are unable to select topics, they will not attend to the map as much as the other two groups who require more time with the map in order determine where to go next (*free*) or how they might have arrived at the current topic (*yoked*).

In addition to aiding navigation and identifying one's location, the map may serve different roles throughout the studying process: an advance organizer at the start, reference point for knowledge construction or monitoring tool while studying, and a review tool at the end. What did learners do at the different points and were there any patterns?

As described earlier researchers presume that eye fixations signal processing of the observed information. The data can describe how learners attend to study materials. So what do eye fixations tell us about learners' attention to the map and text while studying?

The Learner's Studying Experience

Individual differences in motivation and interest may affect learning. Post-studying data asked learners the extent to which they were motivated at the session and their level of interest in the given topic. Did levels of self-reported motivation and interest differ between the treatment groups? Over they study period, did self-ratings of learning change? Are there differences in the reported utility rating of the navigational map by condition group? Was there a relationship between a person's rating and the extent to which they used the map? What explanations do learners provide for their utility ratings? What may we observe as themes, streams and patterns from students' descriptions of their studying experience and what did they find to be easy and challenging? What were the map's strengths, weaknesses and suggested areas for improvement? What comments did learners make about studying experience and navigable map use depending on their treatment group? Finally, what were the global themes from the learner's open-ended responses?

Summary

To conclude, this chapter reviewed the literature on concept maps that serves as the basis for the navigable concept map in this study. The chapter described three main functions, in addition to common theoretical explanations and suggested alternate lens. Consideration of individual differences, task design, and acquiring data during the learning process were proposed. The findings and issues from research to-date influenced the design of the present study. Details about the methodology unfold in the next chapter.

CHAPTER III: METHOD

Participants

I posted advertisements (see *Appendix A*) in print at the Simon Fraser University Surrey campus, online through the general SFU community news and contacted several instructors individually, asking them to promote the study. Students at this mid-sized Canadian university responded with preferred days and times within a 3-week time period (Monday, October 1 to Friday, October 19, 2007) and made appointments via email for any days except Sunday. Sixty-three university students (38 women and 25 men, M = 21.24 years, SD = 3.67) from various disciplines volunteered for financial remuneration upon completing the session. To preserve anonymity, ID numbers represented participants in all data records.

Treatment Groups

When a participant arrived, I assigned him or her to one of three condition groups: *free* (n=21), *clockwise* (n=21) or *yoked* (n=21). I cycled through each group sequentially (i.e. 101, 201, 301, 102...), so in the case of a no-show, the next participant received the subsequent group assignment. Although technically semi-random, I reasoned that random assignment occurred based on when the participant signed up for and attended the session.

Materials

The study consisted of three phases, pre-studying, studying and post-studying; each with its own set of materials. A computer programmer (M. Stanger) and I built a website compatible with Internet Explorer to house all of the study's online components. The site's design fit a 1024 x 768-resolution screen without any scrolling. Prior to the participant's arrival, I entered an ID number on a start page and all pages and data entries thereafter were associated with that participant. The system compiled data into a downloadable Excel spreadsheet. A four-page researcher's script provided details for each step in the study to aid procedural consistency.

Pre-studying Phase

Upon arrival, participants received, reviewed and signed a print-based consent form (see *Appendix B*) that outlined the session's procedures and included components such as contact information and a statement of confidentiality, as required by the university's Office of Research Ethics.

An online "Participant Questionnaire" (see *Appendix C*), requested typical participant demographics (age, sex, major, credit hours, GPA), in addition to information about computer and internet use and online learning experiences (age the student started to use a computer, frequency of internet use, number of online courses taken, experiences with learning online vs. print). The second section contained six open-ended questions associated with the study topic. The general prior knowledge measure aimed to ensure that the questions did not predispose participants to the upcoming topic on novel foods (see *Table 3*). The final section of the questionnaire listed the 52-items from Schraw and Dennison's (1994) Metacognitive Awareness Inventory (MAI) (e.g. "I ask myself periodically if I am meeting my goals".) Participants responded to each statement on a scale from 1 to 10 (completely false to completely true). All fields in the questionnaire required a response.

Table 3: Prior knowledge questions for novel foods topic.

Item
1. What is a gene?
2. What are hybrids (plant or animal, not cars)?
3. Name one technique to create a hybrid plant:
4. Food that is a product or an ingredient made from chemicals or natural resources which have never before been used for nutrition, is called:
5. What technology comprises all processes in which living organisms or parts of them are used to make products, improve features of plants or animals or develop microorganisms for special usage?
6. In Canada, the regulation of foods is the responsibility of which specific group?

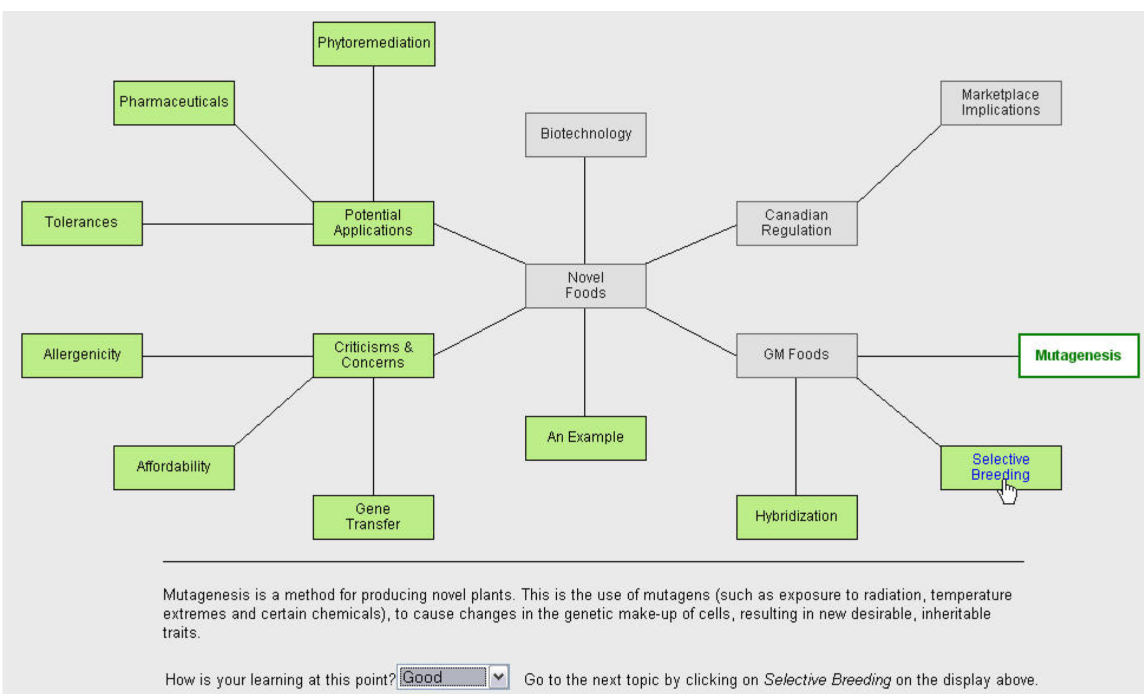
Studying Phase

Prior to studying, participants viewed one of two sets of instructions, depending on their assigned condition group. (For complete instructions, see *Appendix D* for the free condition and *Appendix E* for the clockwise and yoked groups.) Differences in the instructions occurred where participants read, "*You control the viewing order of the topics*", "you will navigate through the topics in a *linear order*" or, "you will navigate through the topics in a *pre-determined order*", for the free, clockwise and yoked treatment groups, respectively.

The studying phase consisted of 18 web pages: 17 topic pages and a start page (see *Appendix F* for an example). Created using Photoshop, HTML, program code written in Perl and associated configuration files, each page consisted of an interactive concept map appearing at the top of the page and text related to the selected topic located at the bottom. The text section included a question with pull-down options inquiring on the participant's feelings about their learning at that point in time (see *Appendix G*). Concept maps may appear in a variety of formats, the map in this study was a radial map, which is in essence a hierarchical concept map. Presenting a radial map, rather than a top-down hierarchical map aimed to encourage participants to select topics in an atypical order (i.e. not left to right or top to bottom). Each box in the map identified a key term and purposefully employed unlabeled, non-directional links to keep the map clean and simple. The boxes were spaced 80-pixels apart from each other to address the eye-tracker's potential margin of error of 40-pixels. The clickable term turned green and was bolded when moused-over.

The programmer and I developed two sets of pages with different navigational functions to address the specific needs of the condition groups. For the *free* navigation group, all topics in the navigational map were clickable (see *Appendix G*). For the clockwise and yoked groups, participants could only click on the term identified in the last sentence of the text (see *Appendix H*). As *Figure 1* illustrates, green boxes signalled topics not yet viewed, while white boxes with bolded green border and text signified the active topic. As participants worked through the topics, grey boxes depicted already viewed topics. On each page, participants answered the required question, "How is your learning at this point?" with available answers being: very good, good, acceptable, poor or very poor. The website recorded the order participants viewed the pages, the duration of each visit in seconds and the response to the "how is your learning" question.

Figure 1: Example of the study in progress for the clockwise group*.



* Active topic = mutagenesis.

The text for the study, "Novel Foods" was adapted from the Government of Canada Biobasics (2007), Health Canada Food and Nutrition (2007), and CSA Illumina (2007) sites and met the copyright terms and conditions as stated on the respective site. I identified seventeen key terms and their relationships. In an attempt to balance the complexity of the topics, each topic's text consisted of two to three sentences, ranging from 39 to 61 words, with an average of 48.8 words. See *Appendix I* for the complete text for each page. All participants in the clockwise group ended on the phytoremediation topic (explanation to follow under the Procedure section); while the last topic varied for the free and yoked condition groups (see *Appendix J*).

Post-studying Phase

I developed two test questions for the study (see *Table 4*). The first question asked the participants to recall what they could remember and indicated the scoring criteria. This question, printed on letter-sized paper, allowed participants to convey what they learned beyond a textual depiction, allowing them to use diagrams and lines as well. Building on the participants' recollection, the second question provided a scenario to apply what they had learned. This online question required a textual response, included scoring criteria and had an unlimited sized text box (see *Appendix K* for the actual form).

Table 4: Test questions.

Cognitive Domain	Question	Scoring
Knowledge (recall)	Please use the space below to indicate everything you can remember about the text you have just studied. Include key concepts and the relationship between them. Point form, lines, and diagrams are acceptable.	You will receive a point for every complete idea and relationship you provide (1/2 points are possible).
Application	You're meeting a cousin over coffee. Your cousin owns a large import company and was just contacted by a potential supplier who has genetically engineered two types of potatoes: one contains additional vitamins and minerals and the other can grow in a wide range of growing conditions. The supplier has asked your cousin to research the possibility of importing and marketing the potatoes and seeds in Canada. Draw upon what you have studied to identify key considerations to your cousin so that he/she can successfully get the potatoes and seeds to the Canadian market. Please write in full sentences, as if you were talking to your cousin.	You will receive points for: 1) identifying key considerations, 2) providing rationales on why they are important, 3) integrating ideas from the text you have studied, and 4) the organization and coherence of your response.

In order to gain a better understanding about learners and their experiences during the study, participants answered online questions about their studying experience, level of motivation and interest on a scale of 0 (not at all) to 5 (extremely), as well as what was easy and challenging for them while studying. Interested in instructional design considerations for future graphic navigational aids, I included five questions requesting feedback on the usefulness of the map as a study aid on a scale of 0 to 5 (not at all to extremely), and open-ended responses on its strengths, weaknesses and suggestions for improvements (see *Appendix L*). Each question required a response and had an unlimited size text-field. Lastly, a Receipt of Payment form (*Appendix M*) documented payment and enabled participants to communicate whether they wanted the results of the study.

Equipment

The experiment took place within a small room with only a computer station and the eye movement equipment and related computer equipment. Participants worked on a

PC running Internet Explorer using a 19" CRT monitor, using a standard mouse and keyboard and sat on a height-adjustable office chair.

The eye tracking system designed by Applied Science Laboratories of Bedford, Massachusetts, recorded participants' eye movements and fixations on the web pages. The core of the system was a PCI card sized digital image processor that tracked the centre of the pupil and the reflection from the corneal surface. The system tracked what the person was looking at by illuminating the eye with a low-level infrared source.

The entire system consisted of several components:

- A pan/tilt optics module (camera) located on the participant's desktop in front of the computer monitor. This module included a built-in, low-level infrared source that would illuminate the eye in such a way that the pupil and corneal reflections could be identified by the video digital image processor,
- The Eye-trac 6000 control unit: a PC-card sized digital image processor that analyzes the video source and tracks the pupil and corneal reflections
- The Flock of Birds control unit would monitor a Velcro-mounted sensor worn on a headband by the participant. As the participant's head moved, the Flock of Bird's control unit would relay head-movement data to the Eye-trac 6000 control unit. The Eye-trac 6000 would adjust the pan/tilt optics module such that it kept the camera's view centred on the participant's eye. This compensated for small head movements made by the participant during the study.

The set-up required two computers: one for the participant to work on which gathered data through Gazetracker™ software and another for the eye movement equipment and eye-tracker calibration software. The set up also included two small monitors that aided in calibrating the eye tracking software for each participant prior to the study. The monitors showed the participant's eye and the desktop scene during the study so that I could ensure that the eye-tracking appeared to be working correctly.

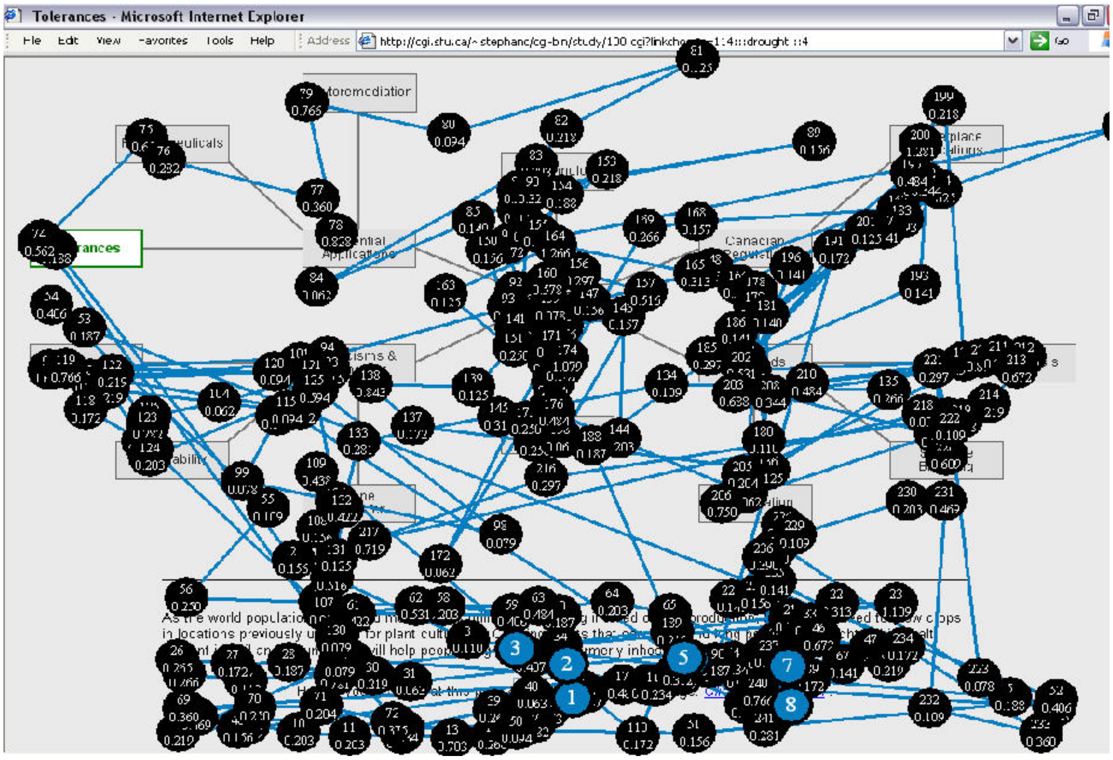
Eye-tracking Software & Traces

Another researcher in the lab had already determined the requirements and set-up the calibration software with the appropriate coordinates (e.g. distance between the scene camera and pan/tilt optics module, viewing angle, key visual points, etc.), which had already been used for several studies. I used the existing set-up and followed the pre-determined processes. Thereafter, setting up a participant on the eye-tracking equipment required ensuring cornea and pupil readings and making necessary adjustments within the software settings and camera controls and establishing a participant's visual range and fixations on specific points on the screen.

After completing the participant's calibration, I activated the Gazetracker™ application. Initially developed at the University of Virginia, this software facilitated the capturing and analysis of raw data streams of eye movement positions and provided three analysis modes: image, video and application analysis. Since this research examined participant's interactions with online content, I chose the application analysis, which recorded gaze positions on the computer screen, mouse clicks, and movement though screens.

As participants worked on the computer, a smaller monitor located beside the researcher replicated the participant's, screen and showed his or her gaze position via cross hairs. Once recorded, the application could replay the events including where the participant looked and all input events, thereby simulating his or her actions. Additionally, a researcher can observe GazeTrails and LookZones. A *GazeTrail* presented the subject's ocular scan path through a coloured path connecting fixation points. Trails illustrate the pattern of a person's gaze (Lankford, 2000). Previous research indicated that fixations might be as short as 50 *ms* up to 500 *ms* with an average of 200-250 *ms* (e.g. Rayner et al., 2005). Hence, for the purpose of this study, I defined 50 *ms* as the minimum time for a fixation. *Figure 2* exemplifies a typical recording of one webpage in this study (time ~40 seconds). The diagram shows three types of data: fixations (black dots with the fixation number and length of time), GazeTrails (blue lines connecting fixation points), and mouse-click input events (blue dots with a number marking the click order).

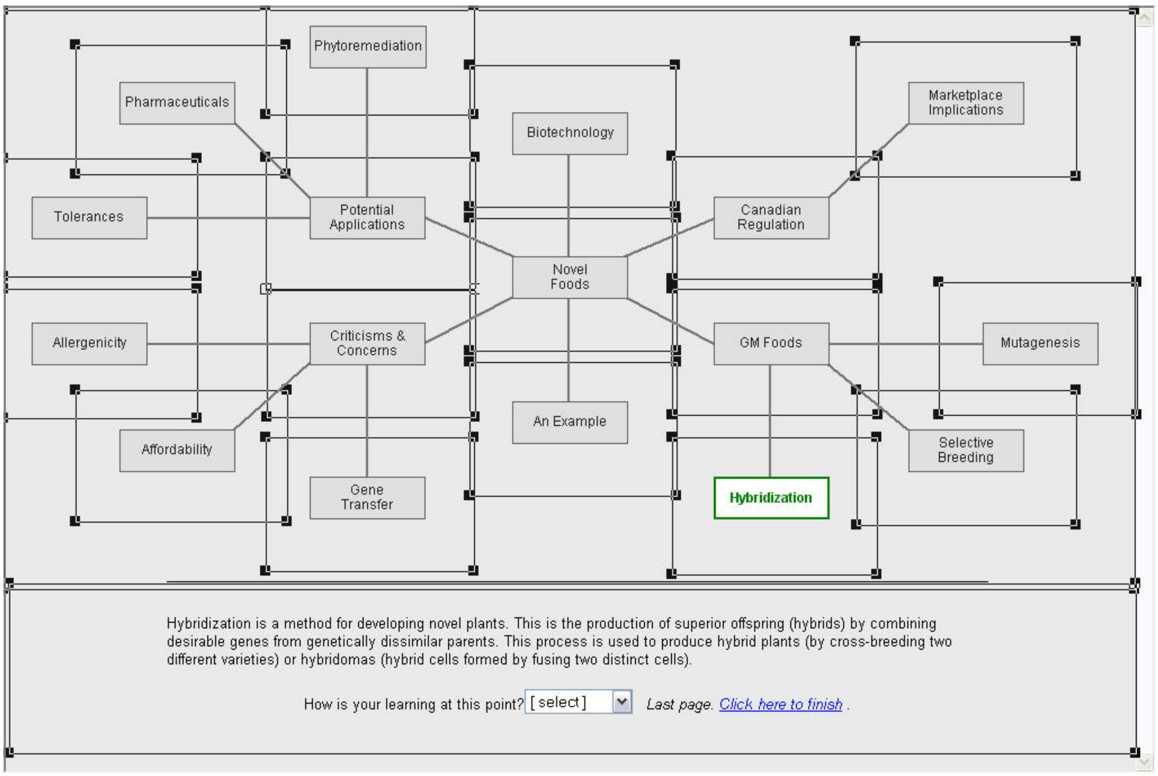
Figure 2: Fixations, GazeTrails and mouse-clicks on a study page.



As seen in the example above, eye-trackers produce vast amounts of data; but to analyze them meaningfully required defining regions of interest referred to as LookZones by GazeTracker™. *LookZones* filter the recorded data and provide measures for areas defined by me, such as the total time spent in a region, percentage of time spent in a region, time until the first fixation in the zone, and number of times a person's eyes fixated on the region. I created LookZones by loading the web page of interest and drawing rectangular regions over the image. To accommodate the maximum potential margin of error (40-pixels), I designed the navigational map with as much space as possible around each topic node and the topic's text located at the bottom of each screen. I identified nineteen LookZones: one of each node, the text at the bottom and the entire map. Consequently, if a person's fixation did not occur within a topic's LookZone, the software would still record the fixation, but within the map or text LookZone. The boxes in *Figure 3* show the 40-pixel boxes around each node's LookZone. After assigning the LookZone with a name and associating it with a LookZone collection, I could apply them to the collected data. However, due to limitations with the application, each of the

17 pages required its own set of LookZones, which I then applied manually for each page, for each participant.

Figure 3: Identified LookZones for the study pages.



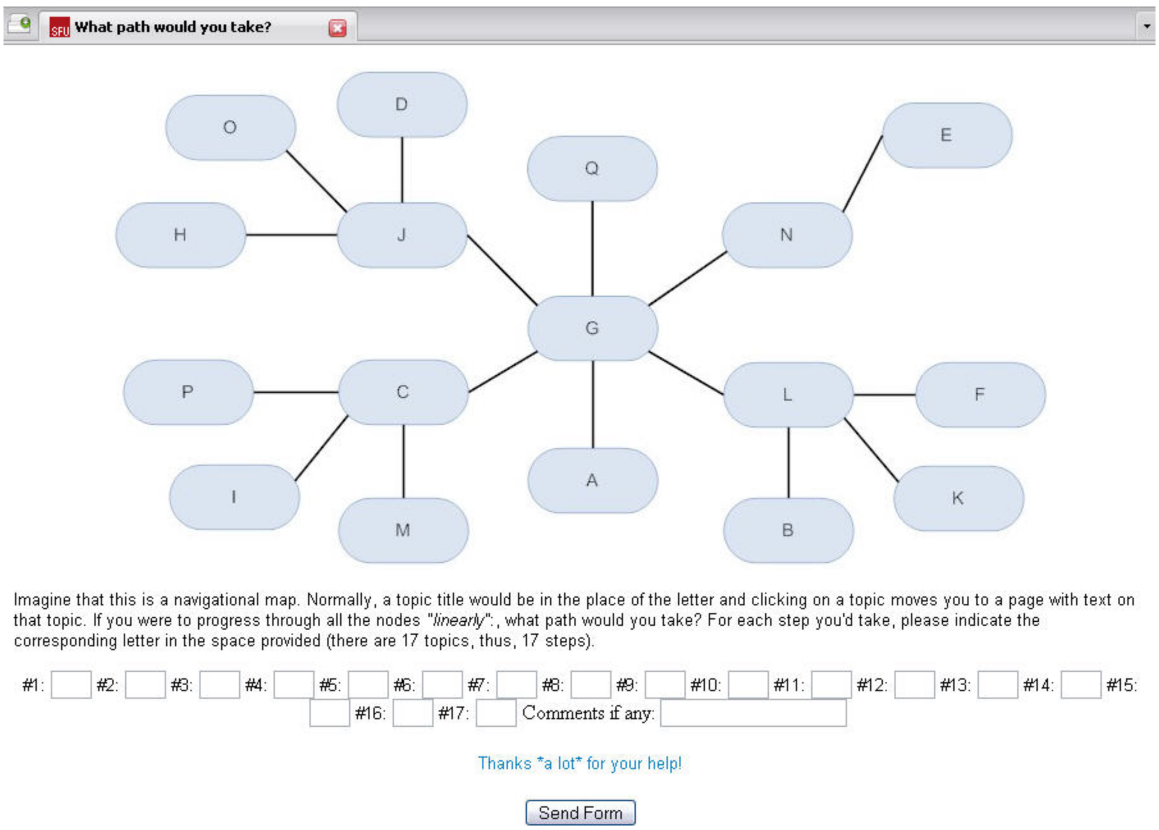
Procedure

Feedback and Pilots

Colleagues and volunteers were instrumental in refining the materials for this study. For example, the original navigational map presented the shorter branch in the top left quadrant. In addition to the potential for participants to start at the left, the shorter branch may also be the "easiest" and predispose participants to the left quadrant. Thus, I moved the shorter branch to the right. In order to determine the direction that the clockwise group would progress, I asked students volunteers to state the path they would take if asked to progress through all nodes "linearly" (see *Figure 4*). Five out of nine respondents evidenced a clockwise direction, radiating from the middle outwards.

This served as the basis for the clockwise group's predetermined order of topics. Volunteers also participated in pilot tests that helped to hone the procedure, establish the times for each component, provide me with practice using the eye-tracking equipment, helped to refine the research materials and improve the interconnections between instructions, tasks, and measures.

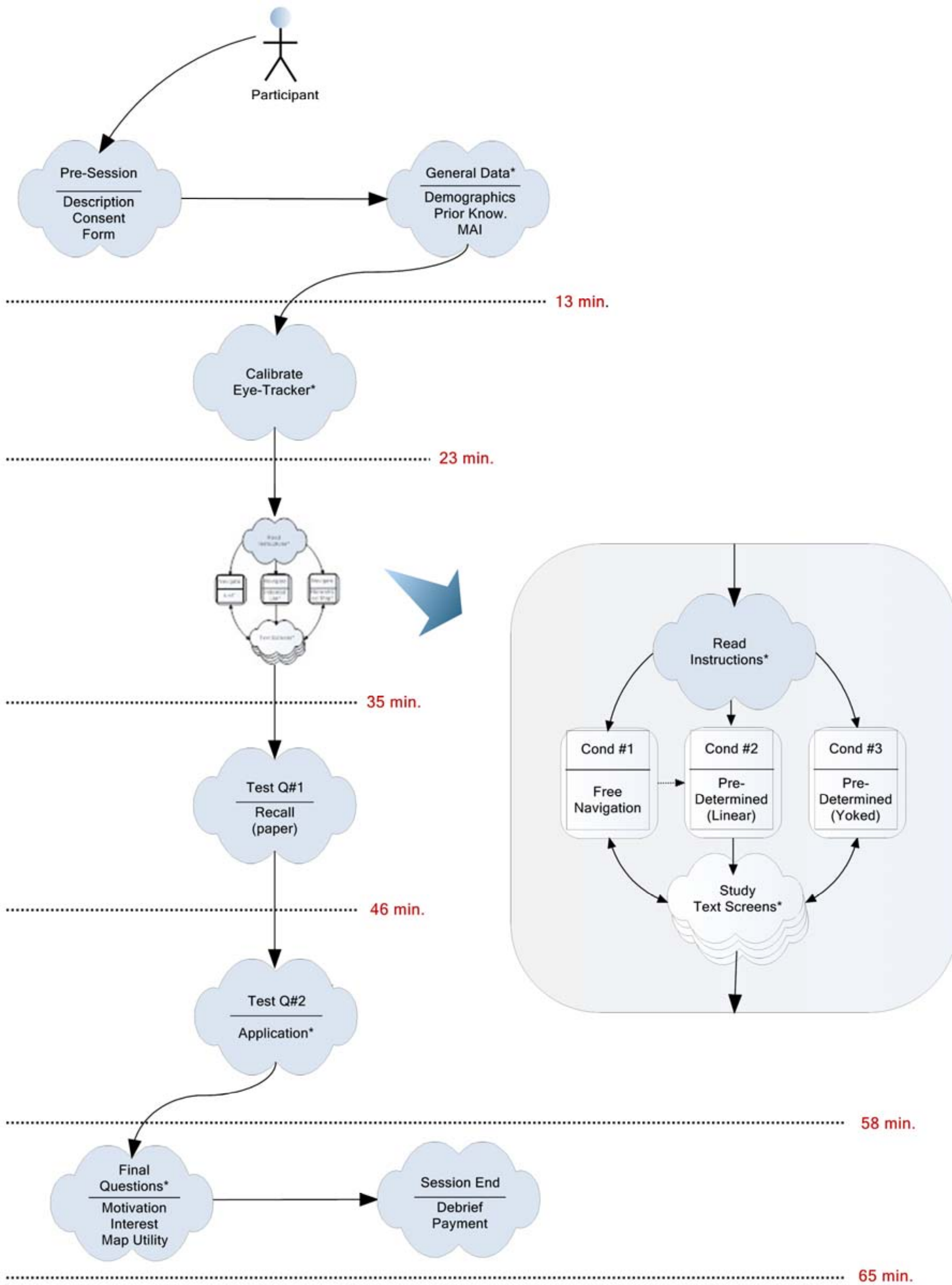
Figure 4: "Linear" path query during materials development.



The Sessions

Through pilot tests, I estimated that the study would take 65-minutes to complete. While *Figure 5* outlines the procedure and time assigned to each component, the next section describes study's procedure for each of the pre-studying, studying, and post-studying and phases.

Figure 5: Session procedure for the three treatment groups.



Pre-studying Phase

Prior to the session, I positioned the chair so that the participant's eyes would be 24-30 inches from the desktop camera. When the volunteer arrived, I requested that the chair remain stationary and then described the session's components and tasks. The participant could end the session at any time, or receive payment of $25 for completing the session. The top scorer on the test questions, for each condition group, would receive an additional $75 at the end of the study. I rationalized that in an authentic learning environment, a grade can be an external motivator. A grade would likely be meaningless to participants in this context: ergo, the cash bonus.

After posing any questions and agreeing to the tasks, the participant completed the consent form and all fields in the online "Participant Questionnaire" within the allotted 10-minutes. Then, while sitting in a comfortable position, the participant secured the headband around his or her head and I placed the sensor over a Velcro patch on the headband, above the participant's left eye. Asked to maintain this sitting position for the duration of the studying period, the participant then looked forward at a screen displaying nine numbers in different areas while I dimmed the lights and calibrated the equipment.

Prior to recording eye movements, the eye movement apparatus required calibration to each participant. As a result, I instructed the volunteer to fixate on nine targets on the screen, one at a time. The targets were positioned in the top-left, top-centre, top-right, mid-left, mid-centre, mid-right, bottom-left, bottom centre and bottom-right areas of the participant's field of view. The system calculated horizontal and vertical correlating factors for the participant's field of view and employed these correlations to compute the location of a fixation for later eye movements.

The amount of time taken to calibrate varied from 3 minutes, up to the allotted 10 minutes. For some volunteers, attempts at calibration failed due to a range of possible reasons such as small pupils, oscillating pupils, participant fatigue, weak or unstable pupil or cornea readings, etc. In spite of the inability to gather eye movement data, consistency across participants was important. Consequently, I continued with the study and activated the recording software while the participant wore the headband and sensor. In total, the pre-study phase took up to 23-minutes.

Studying Phase

Participants took their time to read the instructions as their 10-minute studying time did not begin until they clicked on the "start" button. While the volunteer studied, I watched the eye monitor to ensure pupil and cornea readings and made adjustments accordingly. In a few cases, eye-tracking failed during the study, again possibly due to weak or unstable pupil or cornea readings, fatigue over time, etc. On average, this phase lasted up to 12-minutes. Most participants completed the study time within the assigned time, but a few did not. In these cases, I alerted the participant that his time was up and encouraged him to finish studying all the topics. When the studying time elapsed, the participant removed the headband and I turned on the lights.

Post-studying Phase

The sessions' remaining 30-minutes consisted of several components. First the volunteer completed Question #1 (recall) on paper, followed by Question #2 (application) on the computer. I kept each question strictly to 10-minutes each, communicating when time had lapsed and prompting the participant to finish his thought. Then, he responded to online questions about his studying experience and the navigational map. After debriefing and answering any questions, I paid the participant $25 while he filled out the Receipt of Payment form.

Approach to Data Preparation

Prior Knowledge

I scored the six prior-knowledge questions based on correct answers pre-determined from credible websites (e.g. Health Canada). Participants received a full point for each correct and complete answer and could receive a half point for partial responses on four questions (see *Table 5* for questions and sample answers).

Table 5: Examples of acceptable and partial answers for the prior knowledge measure.

Question	Acceptable Answers (1 point)	Partial Answers (1/2 point)	Incorrect Answers (0 points)
1. What is a gene?	- Part of our genetic material, our genome called DNA which is key for inheritable qualities of living beings	- Strand that contains one's genetic material - Contained in DNA and passed on from generation to generation	- Part of your chemical make-up - A part of your body that makes you different - DNA
2. What are hybrids (plant or animal, not cars)?	- Product of crossing heterogeneous parents - Different plants or animals combined to create a new plant or animal - Mix of/cross between two species	- Mix of two organisms/things - A cross-breed - A cross-between two different lines - A combination of species	- Plant - A better species
3. Name one technique to create a hybrid plant:	- Genetically combining species in labs - Artificial/controlled cross-pollination - Genetic splicing	- Cross-breeding - Mix two different plants together - Cross-pollination - Splicing	- Chemically altering a plant to make it have a certain colour by using a specific dye - Grafting
4. Food that is a product or an ingredient made from chemicals or natural resources which have never been used for nutrition is called:	- Novel food - Genetically modified foods	- N/A	- Xenobiotic - Synthetic - Monosodium Glutimate - Junk food
5. What technology comprises all processes in which living organisms or parts of them are used to make products, improve features of plants or animals or develop microorganisms for special usage?	- Biotechnology - Bioengineering	- N/A	- Genetic engineering - Pollution - Evolution - Fertilizer - Production
6. In Canada, the regulation of foods is the responsibility of which specific group:	- Health Canada (establishes standards & criteria) or Canadian Food Inspection Agency (provides services & enforces)	- Canadian Food Agency	- Food and safety (government) - Government - Canadian food board - Fraser Health Society - Canadian health and food guide

Further Identifying "Map Use"

Chapter I identified five possible functions for the map's use: as an advance organizer, navigational tool, pathway indicator, material-to-be-learned, and a means to monitor and review. Moreover, participants could have employed the navigable concept map while engaging in metacognition, namely regulation of cognition. Unless participants provide contextual information, there is no means to pinpoint the purpose of monitoring and review. In spite of this, in *Table 6* I have attempted to operationally define map use in the far right column, based on MAI categories and items, the five identified functions, and possible data sources. This may be useful when examining learners' self-reports.

Table 6: Possible "map use" during regulation of cognition using MAI categories and items.

Categories	#	Item	How might the map aid this?
Planning	4	I pace myself while learning in order to have enough time	Advance organizer: by reviewing the map before studying
	42	I read instructions carefully before I begin a task.	
Info Management Strategies	13	I consciously focus my attention on important information.	Monitor & review; material-to-be-learned: by observing and fixating on topics and the lines showing relationships
	41	I use the organizational structure of the text to help me learn.	
	48	I focus on overall meaning rather than specifics.	
Monitoring	21	I periodically review to help me understand important relationships.	Monitor & review: by observing and fixating on topics and the lines showing relationships
Debugging	51	I stop and go back over new information that is not clear.	Monitor & review: fixating on topics and lines, returning to the map and re-examining components
	52	I stop and reread when I get confused.	
	24	I summarize what I've learned after I finish.	Final review of the map before ending the study session

Grading the Test Questions

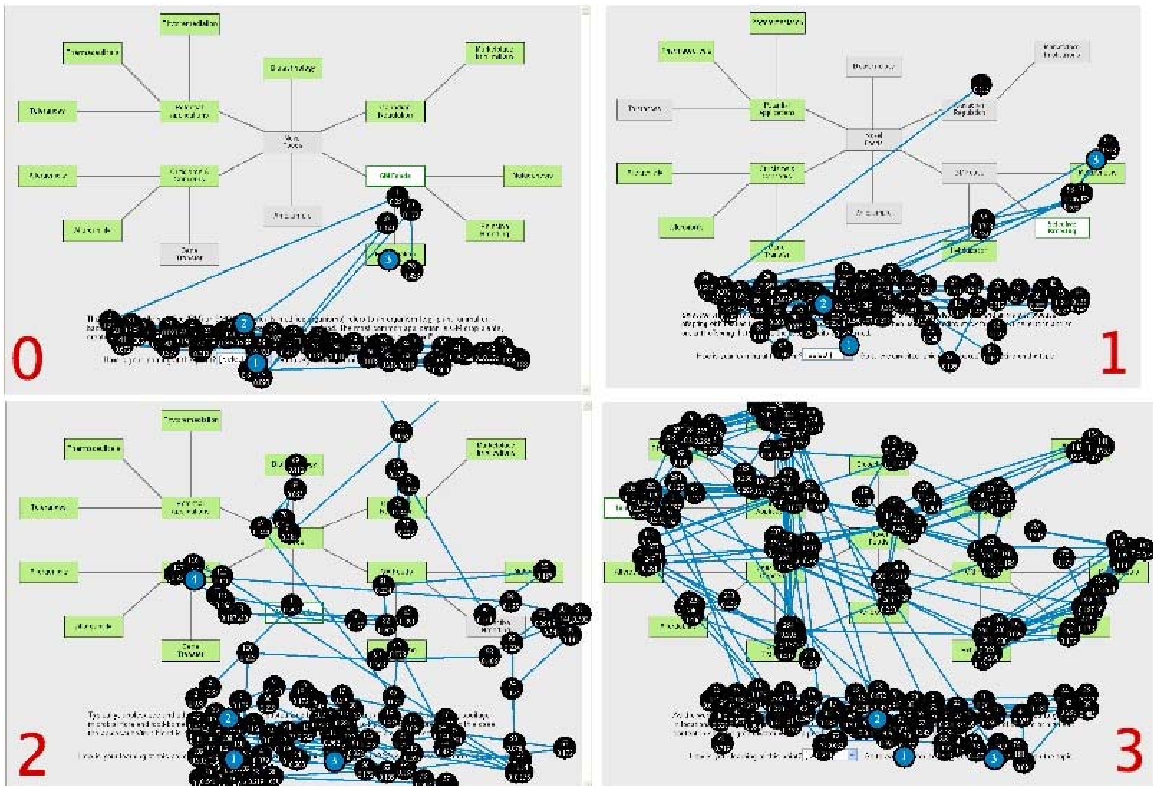
To examine condition effects on achievement, the two test questions required grading. A colleague (D. Jamieson-Noel) and I independently graded student responses to the two questions. For question #1, participants received a point for each full statement that they recalled from the text content or for a description of relationships between topics, half points for partial responses and quarter points for key terms. When students wrote a key term within a text response without any indication of its relationships to other terms, the exact wording was required to obtain a quarter point. On the other hand, the scorers accepted a response that captured the key idea or slight deviations in wording (e.g. applications vs. potential applications) in a pictorial response if the participant mapped the term and its relationship correctly.

For question #2, participants received a full point for every issue and rationalization based on the original text and a half point for a partial response (e.g. identification of an issue, but not the rationale). For both questions, discussion ensued until the coders reached consensus. Calculations for interrater reliability for each questions yielded, $r = .95$, $p < .01$ (rater #1) and $r = .97$ (rater #2), $p < .01$ for both questions.

Eye movement Data

The GazeTracker™ application collects detailed data about each LookZone, but it does not present data in a manner that demonstrates the overall viewing pattern for the map (see *Figure 6*).

Figure 6: Levels of map fixation activity for a study page*.



* Map fixation activity is not defined as including fixations in the text area.

Learners may have engaged study strategies such scanning the map to acquire an overview or reviewed the map before ending the session. To obtain this data, I individually examined the 18 screens and created five variables based on the extent to which participants fixated on the map nodes in the first and last screens, and three general points while studying (beginning, middle and end). If learners fluctuated between screens, a number denoting the overall activity was assigned for that general segment. *Table 7* outlines the point assignment, description and approximate number of nodes and fixations per node.

Table 7: Defining the level of activity for map use.

Point Assignment	Description	Number of Nodes	Number of Fixations per Node (approx.)
0	No activity within the map beyond navigation	2 (nodes for the current topic and the next selected topic)	Did not matter
1	Limited viewing of other nodes	3 to 6 nodes	1+ fixation
2	Moderate viewing of nodes	6 to 13 nodes	1+ fixation
3	a) Intensive viewing of most nodes several times or b) almost all nodes at least once	a) 12+ nodes b) 17 to 18 nodes	a) 3+ fixations b) 1 fixation

After defining the LookZones, the fixation data was exported into either 18 separate Excel spreadsheets or one extensive text document; neither of which could be imported into a statistical package due differences between rows within the document. Given the sheer amount of data and inability to compute or combine data to form more general variables (because the data could not be imported), I had to be selective. Overall data for each of the 18 screens (e.g. fixation frequency, total time fixated, total time not fixated, etc.) and data for the text and map LookZones (similar to the overall data, plus information such as number of fixations before arrival and duration of total fixations before arrival) were imported into an SPSS database. Data were also imported for the active topic's LookZone (i.e. if a student was on the novel foods screen, data for the novel foods LookZone were imported). This resulted in over a thousand variables for the eye movement data alone.

Recoded and Computed Variables

The values for most variables ranged from the negative to positive or low to high (0 = not at all; 5 = extremely). After data collection, I observed that two variables had reversed scales. For the "internet use" variable 1 = several times a day while 7 = a few times a year or less. The "how is your learning?" self-rating for each topic while studying ranged from 1 = very good to 5 = very poor. Therefore, for consistency across variables and to alleviate potential confusion, these two variables were recoded. The age that a participant reported that he or she started to use a computer was subtracted from his or her current age to produce the "computer_years" variable, representing years of computer use.

From the 52-statements, I summed responses to statements for each of the sub-categories of the Metacognitive Awareness Inventory to produce scores for knowledge of cognition and regulation of cognition (number of statements in parentheses). The scores for each group of sub-categories were summed, resulting in scores out of a possible 170 and 350. *Table 8* summarizes the key data for this study.

Table 8: Summary of key data.

Source	Type	Details

Questionnaire	Participant information	• Demographics
		• Prior knowledge
		• MAI
		  ▪ knowledge of cognition
		    ▪ declarative knowledge
		    ▪ procedural knowledge
		    ▪ conditional knowledge
		  ▪ regulation of cognition
		    ▪ planning
		    ▪ information management strategies
		    ▪ monitoring
		    ▪ debugging
		    ▪ evaluation

Website	Data about topics while studying	• Order of topics viewed • Time on each topic • "How's your learning?" self-rating per topic
*Gaze-tracker	Fixations and GazeTrails	• LookZone data (time, frequency, percentage, etc. per selected LookZone, per study page, per participant (4 x 18 x 35) • Level of map activity over time (start screen, 3 other points, and the end topic) • Screen shots of fixations (for verification/activity)
Question #1	Recall measure	• Overall score
Question #2	Application: scenario	• Overall score
Questionnaire	Study experience	• Self-ratings: interest, motivation • Open-ended: description of studying experience, what was easy/challenging
	Navigational map experience	• Rating: map's utility • Open-ended: rationale, strength, weakness, suggestions

* For a limited number of participants (*n*=35)

CHAPTER IV: RESULTS

Overview

To recap and elaborate, the study endeavoured to achieve these goals: (1) to examine whether knowing one's location within the navigable concept map or control over topic sequence affects online studying and achievement, (2) to investigate the relationship between metacognitive awareness, self-regulated learning, prior knowledge, knowledge of cognition and regulation of cognition as captured by the MAI, self-reported motivation, self-reported interest, and map utility, and studying and achievement, in relation to navigable concept map use, and (3) to observe the studying process and learners' experiences using the map.

Being informed about learners: who they are, what they do, what works or does not work for them is just as important as examining a specific experimental effect. Participants in this study are a sample of today's learners and informing educators about them at multiple levels may enable better-met learning needs. Consequently, I have collected and presented data toward this aim. This chapter begins with demographics and educational background information about the participants, followed by a section on their computer and online experience.

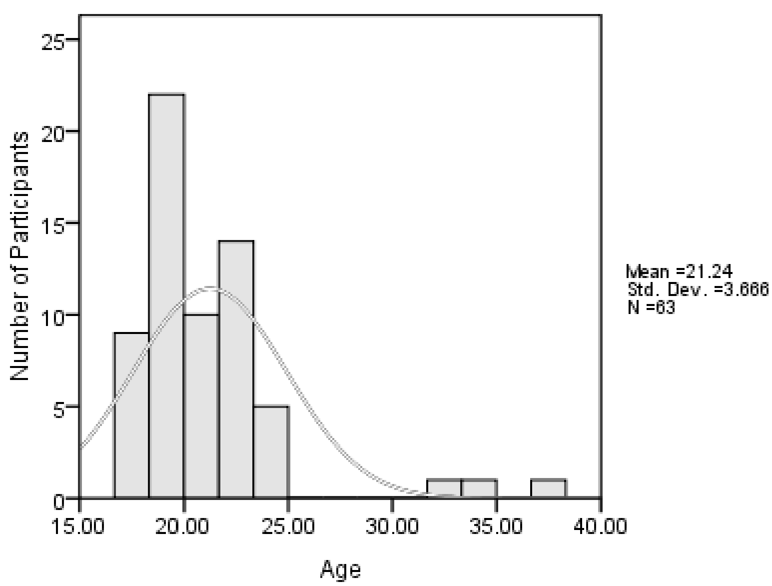
Later sections of this chapter address the study's research questions as identified in Chapter II, starting with whether differences existed between the conditions groups prior to treatment and differences in studying and achievement thereafter. Next, this study reports on the learners' experience and exploration of predictors and relationships to achievement. An important caveat for these two sections is the acknowledgement of small group sizes (n = 21 per group) and because of this, the results of this study provide suggested directions for future research. This chapter ends with themes, streams and patterns derived from the comments made by participants about both their studying experience and the map's utility, which serve as the basis for Chapter V's instructional design considerations. Analyses included all participants (n = 63), for each treatment group (n = 21) or for all learners where eye-tracking data was successfully collected (n = 35). *Appendix N* provides the correlation coefficients for the key and composite variables.

The Participants

General Demographics

Sixty-three participants; 38 females (60%) and 25 males (40%) completed the study; their ages ranged from 17 to 38 years (M = 21.24 years, SD = 3.67) with the majority of students in their late teens or early 20's. I identified three extreme cases (age $\geq$ 33). Although the distribution is strongly leptokurtic (*Kurtosis* = 9.33, SE = .60) and positively skewed (*Skewness* = 2.73, SE = .30), I reasoned that the majority of undergraduate students are in their early twenties and the student population includes mature students, albeit in smaller numbers than the majority of undergraduate students. Therefore, the data was acceptable and the extreme cases were kept (see *Figure 7* for the distribution.)

Figure 7: Participants' age distribution.



Educational Background and Prior Knowledge

Participants varied in their majors or intended specializations (see *Table 9* for the total by discipline and condition group) and ranged from starting their first semester to completing their sixth year of post-secondary studies (0 to 6.4 years based on a calculation of 30 credits per year; M = 2.3 years, SD = 1.48). Eight participants started post-secondary studies in the current semester. These students reported high school percentages that I converted to equivalent GPAs based on the university's standards. The GPAs for all participants ranged from 1.00 to 4.10 with M = 3.12 and SD = .58.

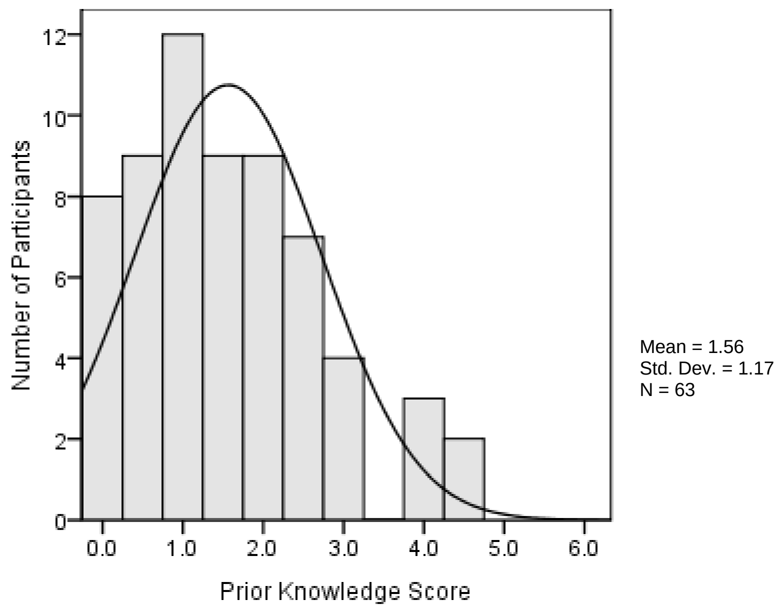
Table 9: Participants' major or intended specialization.

Category Code	Major	Free	Clockwise	Yoked	Total
0	Undecided	2	3	2	7 (11%)
1	Communication	1	3	1	5 (8%)
2	School of Interactive Technology; Interaction Design	5	4	3	12 (19)%
3	Computing Science	0	1	0	1 (2%)
4	Biology	0	1	2	3 (5%)
5	Accounting; Business; Finance; Economics	9	3	8	20 (32%)
6	Criminology; Political Science; Psychology; Sociology	1	4	4	9 (14%)
7	Kinesiology	2	2	0	4 (6%)
8	Actuarial Science; Math	1	0	1	2 (3%)

*When a participant reported two majors, I selected the first

Scores ranged from 0 to 4.5 out of a possible 6 marks (M = 1.56, SD = 1.17) on the prior knowledge measure. Most participants responded correctly or made a partially correct response to the first question, which asked them to define a gene. Incorrect or "don't know" responses increased with each question, suggesting an increase in difficulty or specific knowledge in subsequent questions. As a result, 8 participants (13%) demonstrated no knowledge (score = 0), 39 participants (62%) low knowledge (score = 0.5 to 2), 14 participants (22%) moderate knowledge (score = 2.5 to 4) and 2 participants (3%) high knowledge (score = 4.5 to 6). *Figure 8* illustrates the distribution of prior knowledge scores.

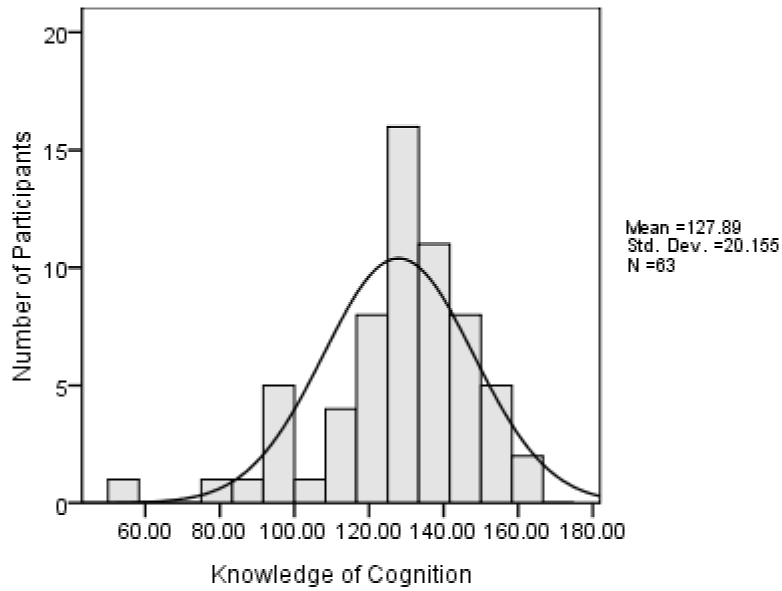
Figure 8: Scores for prior knowledge about novel foods.



Metacognitive Awareness Inventory (MAI) Scores

I calculated self-reported knowledge of cognition and regulation of cognition scores from the Metacognitive Awareness Inventory's (MAI) 52 questions. Knowledge of cognition scores ranged from 54 to 164, out of a possible 170 points. The data contained two extreme outliers $\leq$ 81. *Figure 9* depicts a relatively normal distribution (*M* = 127.89, *SD* = 20.16). The distribution is leptokurtic (*Kurtosis* = 2.03, *SE* .60) and negatively skewed (*Skewness* = -1.10, *SE* = .30). Subcategory results showed: declarative knowledge *M* = 60.62, *SD* = 9.95; procedural knowledge *M* = 29.71, *SD* = 5.90; and conditional knowledge *M* = 37.56, *SD* = 6.23. The maximum possible scores were 80, 40, and 50, respectively.

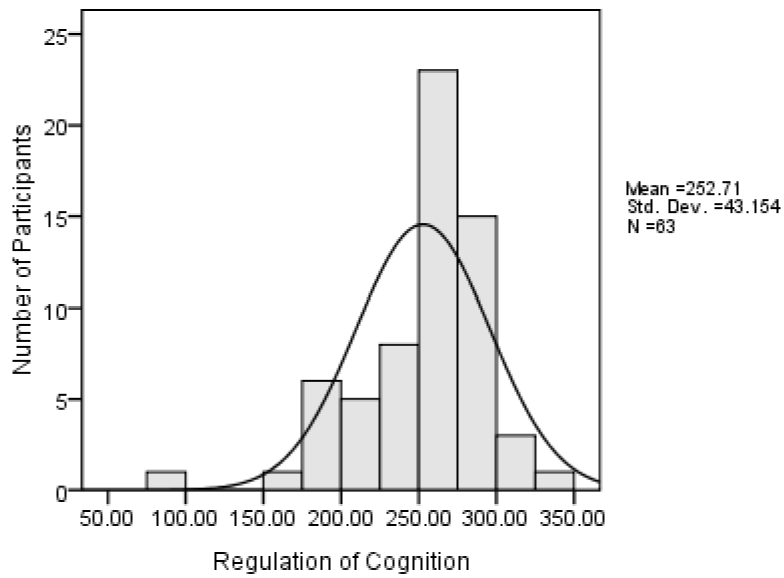
Figure 9:	MAI self-reported knowledge of cognition scores.



* Possible range: 0 to 170

Self-reported regulation of cognition scores ranged from 77 to 336, out of a possible 350 points. The data revealed two extreme outliers ≤ 154. (One subject was also an outlier in the knowledge of cognition measure). The distribution of scores in *Figure 10* depicts a normal distribution (M = 252.71, SD = 43.15). Similar to the knowledge of cognition data, the distribution for regulation of cognition is leptokurtic (*Kurtosis* = 3.44, *SE* .60) and negatively skewed (*Skewness* = -1.32, *SE* = .30). Subcategory results indicated: planning M = 47.00, SD = 9.77; information management strategies M = 75.52, SD = 13.56; monitoring M = 49.10, SD = 10.95; debugging M = 39.51, SD = 6.73 and evaluation M = 41.59, SD = 8.30. The maximum possible scores were 70, 100, 70, 50 and 60, respectively.

Figure 10: MAI self-reported regulation of cognition scores.



* Possible range: 0 to 350

Computer and Online Experience

The age at which participants started using a computer varied from 4 to 28 years old (M = 9.67, SD = 3.99). The correlation between participants' current age and age they started using a computer revealed a statistically detectable relationship (r = .49, p < .001). This suggests a trend where the younger a student, the earlier he or she started using a computer. See *Figure 11* for the distribution. Subtracting the age of first computer use from one's current age yielded the number of years the participant has been using a computer, which ranged from 3 to 26 years (M = 11.57, SD = 3.86).

Figure 11: Current age by age of first computer use.

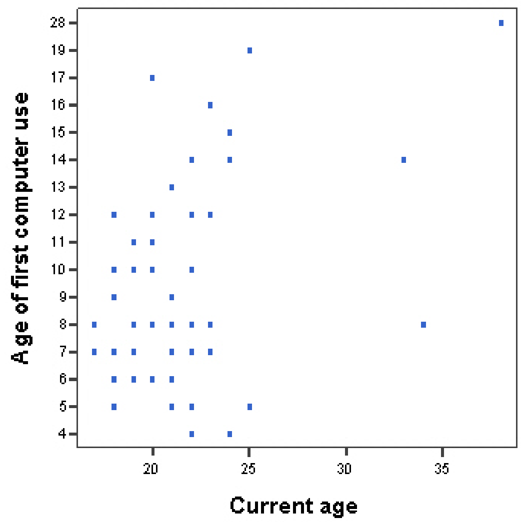
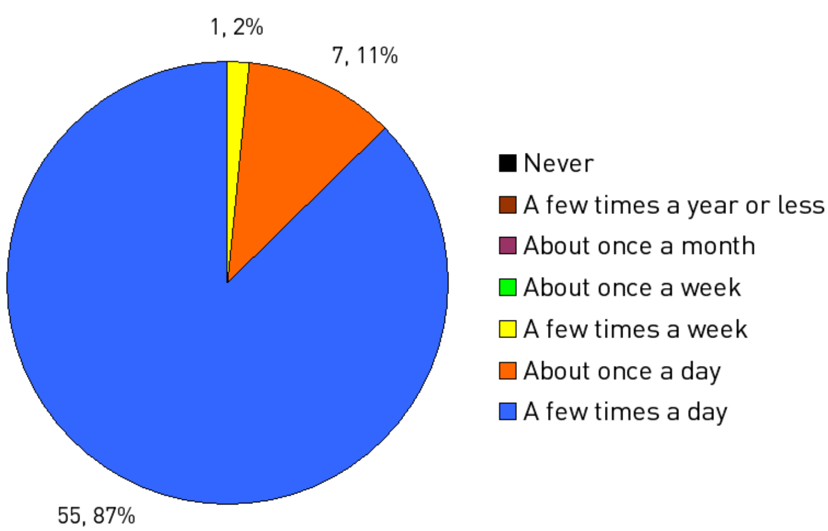


Figure 12 depicts students' reported use of the internet. It appears that internet and computer use are prevalent in the lives of today's student. All students use the internet at least a few times per week, with one person (2%) reporting using it a few times per week, seven people (11%) use it about once a day and the majority, a few times per day (n = 55, 87%). Examining Spearman's rho for age and internet use (rho = -.12, p = .36) did not yield a detectable relationship.

Figure 12: Current internet use.



The participants varied in their experience in learning with online materials, having taken from 0 to 25 courses (*M* = 5.81; *SD* = 4.74). I identified two extreme cases (number of courses ≥ 20). After examining the cases, distribution and observing *Skewness* = 1.67, *SE* = .30, the outliers were kept. Spearman's *rho* = .39, *p* = .002 suggests that learners with more credits reported having taken more courses with online learning materials. *Figure 13* shows the distribution of courses. The data suggest that learners will study online materials in at least a few courses during their academic career.

Figure 13: Number of courses taken with online study materials.

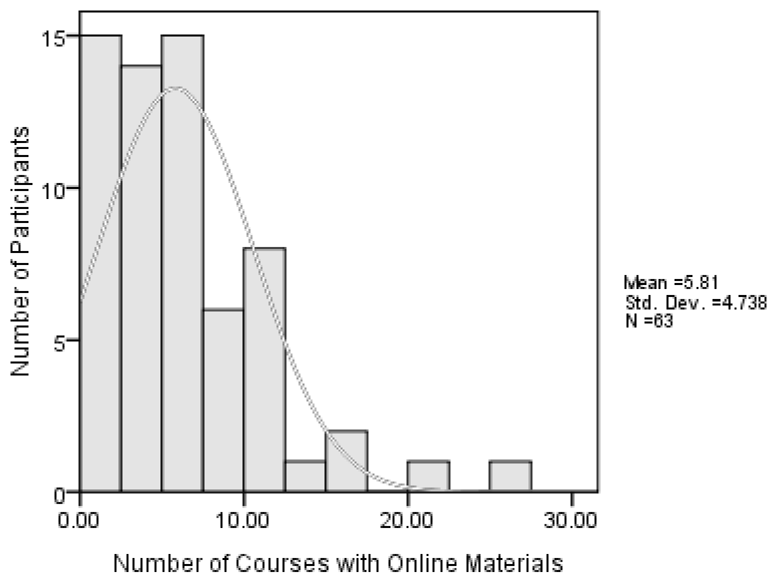
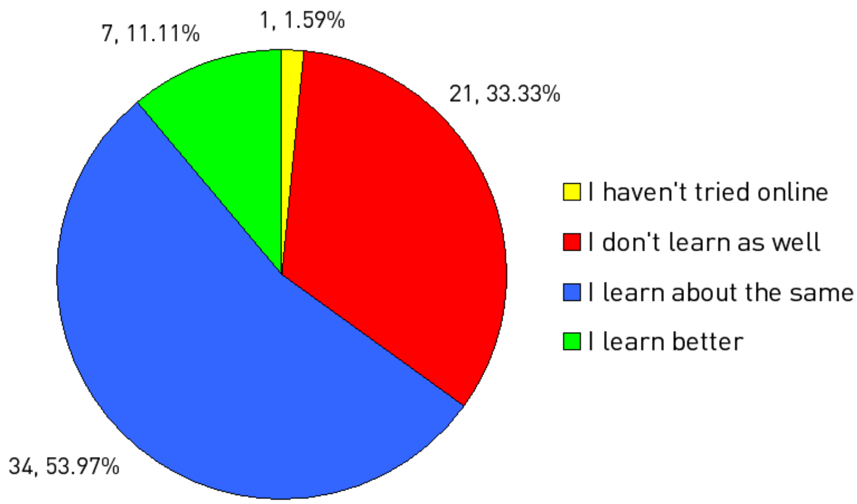


Figure 14 describes students' perceptions on how well they learn with online versus print-based materials. A little over half of the participants (*n* = 34, 54%) reported that their learning occurs about the same, while a third (*n* = 21, 33%) stated that they do not learn as well online, and about a tenth of participants (*n* = 7, 11%) reported learning better online. One person had not yet experienced online learning (*n* = 1, 2%). Reported learning ability was not detectably associated with age, but rather with the number of courses one had taken with online learning materials: Spearman's *rho* = .25, *p* = .04. The

more experience participants had learning online, the more positive their perceptions on how well they learned.

Figure 14: Self-report of learning with online vs. print materials.



Relationships between Independent Variables

Table 10 summarizes the correlations and alphas for the independent variables. Most of the relationships pertinent to this research were described in previous sections. Other noteworthy relationships are between the MAI scores, GPA and age. Perceived knowledge of cognition and regulation of cognition were strongly correlated $r = .81$, $p < .001$ supporting Schraw and Dennison's (1994) finding and supposition that they work together to help students' self-regulation. Correlations between GPA and knowledge of cognition and between GPA and regulation of cognition showed that learners with higher GPAs also had higher scores for perceived knowledge of cognition and regulation of cognition: $r = .45$, $p < .001$ and $r = .27$, $p = .03$, respectively. Cronbach's $\alpha = .55$ for prior knowledge. This may be explained by the design of the instrument where I developed the six questions with the intention for them to vary on their level of specificity, reasoning that learners that are more knowledgeable may know more details about novel foods. Deleting one of the items would not have improved Cronbach's alpha. The output from the analysis indicated that in most cases, a decrease in internal consistency would occur; $\alpha = .42$ τo .56.

In general, self-reported knowledge and regulation of cognition scores appeared to be high. Building on the idea that older, more experienced learners may be more knowledgeable about cognition than adolescents through their self-reports (Schraw & Moshman, 1995), I posited that age might be associated with experience and one's ability to gauge or be more realistic in reporting one's level of self-regulation. Therefore, I examined correlations and found that age was negatively associated with knowledge and regulation of cognition scores, namely $r = -.31$, $p = .01$ and $r = -.39$, $p = .002$. It did not seem logical to surmise that older learners are worse in their self-reported knowing and regulating cognition, but rather that they may be more realistic or accurate in their self-reports.

Table 10: The relationship between the independent variables.

	GPA	Age	# of Credits	Computer Age	Internet Use	Online Courses	Comfort Learning Online	Computer Years	Prior Know. α = .55	Know. of Cognition α = .86	Reg. of Cognition α = .91
Sex	.82	.44	.78	.41	.11	,54	.23	.52	.31	.77	.87
GPA	1.00	-.26*	.17	-.40***	.25	-.04	.10	.16	.20	.45***	.27*
Age		1.00	.45***	.49***	-.12	.15	-.07	.44***	.16	-.31*	-.39**
# of Credits			1.00	.02	.06	.39**	-.06	.41***	.22	.05	.05
Computer Age				1.00	-.23	-.02	-.10	-.57***	-.12	-.21	-.28*
Internet Use					1.00	.13	.01	.15	-.07	.11	.02
Online Courses						1.00	.25*	.07	-.02	-.13	-.08
Comfort Learning Online							1.00	.09	-.04	.15	.05
Computer Years								1.00	.28*	-.09	-.08
Prior Know.									1.00	.20	.02
Know. of Cognition										1.00	.81***
Reg. of Cognition											1.00

* $p < .05$, ** $p < .01$, *** $p \leq .001$
Reported statistics used the lowest level measures (nominal, ordinal, interval): *Cramer's V* → Sex; *Spearman's rho* (two-tailed) → Internet Use, Online Courses, Comfort Learning Online; *Pearson correlation* (two-tailed) →GPA, Age, # Credits, Computer Age, Computer Years, Prior Knowledge, Knowledge of Cognition, Regulation of Cognition.

Investigating Group Differences Prior to Treatment

As stated in Chapter III, I assigned the condition groups in a rotating order (1, 2, 3, 1, etc.) Although this is technically semi-random sampling, random assignment occurred through appointment scheduling and when participants arrived. A MANOVA examined the possibility that participants differed between the groups prior to treatment: prior knowledge, knowledge of cognition, regulation of cognition, GPA, number of credits completed at the time of the study, age, number of courses with online materials, and age the student started using a computer may account for differences between the three groups.

The multivariate analysis evidenced that group differences prior to treatment were not statistically detectable, Pillais Trace exact $F(1, 62) = 1.23$, $p = .25$, effect size = .15. Statistically detectable differences were found on univariate tests where $p < .05$: the number of courses taken with online materials to be studied, $F(2, 60) = 3.29$, $p = .04$ and knowledge of cognition scores, $F(2, 60) = 3.35$, $p = .04$. To avoid capitalising on a possible Type I error and since some univariate test differences are possible, I considered the multivariate result and treated the groups as the same for all analyses hereafter.

Map Effects and Metacognitive Awareness Influences

The first sub-section concentrates on analyses with the complete data set for each group. I examine map effects on studying and achievement through statistical analyses to identify possible relationships and effects. The subsequent sub-sections are more exploratory in nature where I investigate models for predicting learning self-ratings, recall and application measures. Through eye-movement data, we can glimpse the process of studying and how learners use the navigable concept map such as the level of attention and the amount of time spent on the map. The chapter concludes with themes, streams and patterns from learners' descriptions of their studying experience and map use.

Findings through Statistical Analyses

Data for the following analyses were collected from all participants ($n = 63$), except for the topic selection analysis, which is only applicable to the learner control (free) group.

Map Effects on Studying

This section examines self-ratings of learning while studying: Did differences in learner control over topic selection contribute to detectable differences in self-ratings of learning for the treatment groups: (1) learners who control the order in which they study the topics (free group), (2) learners who are guided in an instructionally rationalized sequence (clockwise), and (3) learners who are directed in a peer-rationalized sequence (yoked)? The treatment influences the studying experience and possibly learners' perceptions of their learning as a result.

> H_1: Learners in the yoked group, who lacked control over topic selection and experience peer-rationalized sequences, will self-rate their learning more negatively than learners in the free group who had full control over topic selection. Learners who lacked control and for whom the logic of topic navigation may not be clear will find the learning experience possibly more confusing or less meaningful. Learners who control their study sequence may be expected to provide more positive self-ratings.
>
> H_0: Learners who have control over the sequence of the study topics and learners who have a peer-predetermined sequence will not significantly differ in their self-ratings of learning.

Learners self-rated their learning at the end of each topic, hence 17 times during the study session. *Table 11* provides the adjusted means accounting for GPA and prior knowledge, observed mean scores, standard deviations and confidence intervals for each self-rating of learning over the duration of the study period (17 topics). The clockwise group appears to start out with higher self-rating of learning, but the differences between the self-ratings for each group appear to be small.

Table 11: Self-ratings of learning by study topic means and effect sizes (η^2) by group.

Rating on Learning	Free					Effect	Clockwise					Effect	Yoked					Effect
	Adj. M	*Obs. M*	*SD*	*Low. CI*	*Upper CI*	*Free-CW*	*Adj. M*	*Obs. M*	*SD*	*Low. CI*	*Upper CI*	*CW-Yoked*	*Adj. M*	*Obs. M*	*SD*	*Low. CI*	*Upper CI*	*Yoked-Free*
1	3.64	3.67	.73	3.33	4.00	.053	4.00	4.00	.71	3.68	4.32	.053	3.69	3.67	.73	3.33	4.00	.000
2	3.71	3.71	.85	3.33	4.10	.085	4.19	4.19	.75	3.85	4.53	.145*	3.62	3.62	.67	3.31	3.92	.004
3	3.80	3.81	.68	3.50	4.12	.014	4.00	4.00	.95	3.57	4.43	.023	3.78	3.76	.63	3.48	4.05	.001
4	3.78	3.81	.40	3.63	3.99	.005	3.90	3.90	.94	3.48	4.33	.020	3.70	3.67	.73	3.33	4.00	.015
5	3.88	3.90	.70	3.59	4.22	.062	4.23	4.24	.63	3.95	4.52	.157**	3.70	3.67	.73	3.33	4.00	.028
6	3.87	3.90	.77	3.55	4.25	.009	4.05	4.05	.81	3.68	4.41	.061	3.67	3.67	.73	3.33	4.00	.026
7	4.05	4.10	.77	3.75	4.45	.000	4.09	4.10	.77	3.75	4.45	.065	3.77	3.71	.72	3.39	4.04	.065
8	3.54	3.57	.87	3.18	3.97	.011	3.76	3.76	.94	3.33	4.19	.023	3.56	3.52	.60	3.25	3.80	.001
9	3.50	3.52	.98	3.08	3.97	.008	3.66	3.67	.66	3.37	3.97	.004	3.59	3.57	.81	3.20	3.94	.001
10	3.71	3.71	.78	3.36	4.07	.003	3.81	3.81	.87	3.41	4.21	.004	3.71	3.71	.56	3.46	3.97	.000
11	3.18	3.24	.94	2.81	3.67	.009	3.42	3.43	1.08	2.94	3.92	.000	3.50	3.43	.81	3.06	3.80	.012
12	3.61	3.62	.87	3.23	4.01	.007	3.76	3.76	.83	3.38	4.14	.001	3.82	3.81	.87	3.41	4.21	.012
13	3.94	3.95	.81	3.59	4.32	.003	3.85	3.86	.91	3.44	4.27	.009	4.02	4.00	.63	3.71	4.29	.001
14	3.69	3.71	.90	3.30	4.13	.001	3.66	3.67	.86	3.28	4.06	.004	3.79	3.76	.70	3.44	4.08	.001
15	3.69	3.71	.90	3.30	4.13	.001	3.66	3.67	.80	3.30	4.03	.008	3.84	3.81	.87	3.41	4.21	.003
16	3.90	3.90	.83	3.53	4.28	.008	3.76	3.76	.77	3.41	4.11	.001	3.72	3.71	.78	3.36	4.07	.014
17	3.47	3.48	1.03	3.01	3.95	.005	3.62	3.62	1.12	3.11	4.13	.001	3.68	3.67	.80	3.30	4.03	.011
Sum/17	3.60	3.64	.52	3.40	3.88	.014	3.78	3.77	.61	3.49	4.05	.028	3.62	3.60	.44	3.40	3.80	.002

* $p < .05$, ** $p \leq .01$

A MANCOVA with GPA and prior knowledge as covariates revealed no detectable differences between the three groups for the seventeen self-ratings of learning: Pillais Trace exact $F(1, 62) = .89$, $p = .63$, effect size = .26. This indicates that the level of control learners had over topic sequencing did not affect their self-ratings of learning. Furthermore, to avoid committing a type I error when the multivariate test indicated that there were no differences, I did not proceed with univariate tests.

Map Effects on Achievement

1. Were there any differences in recall and application scores between learners (1) who control the order in which they study the topics, (2) who are guided in an instructionally rationalized sequence, and (3) who are directed in a peer-rationalized sequence?

   H_1: Learners who control the topic sequence (*free*) will perform better on the achievement measures compared to learners who were directed in a discernable pattern (*clockwise*) or learners guided by a peer's selection (*yoked*).

   H_2: Learners who are guided through the content in an instructionally rationalized order (*clockwise*) will score higher than the other two groups.

   H_0: There will be no differences between the three groups on the achievement measures.

To examine the relationships between the recall and application measures and the other variables, correlations were calculated. As noted in *Table 12*, the relationship between the two achievement measures was strongly correlated overall and for the free and clockwise groups. The table also shows the variables, which had detectable relationships with either achievement score. GPA and prior knowledge were identified to have detectable relationships with the recall score and GPA was related to the application score. Reported interest and map usefulness also had detectable relationships with both achievement measures, whereas motivation was only significantly related to the recall score.

Table 12: Correlations for detectable relationships between the recall and application measures and other variables

Variable	Recall (Question #1)				Application (Question #2)			
	All (n = 63)	*Free (n = 21)*	*CW (n = 21)*	*Yoked (n = 21)*	*All (n = 63)*	*Free (n = 21)*	*CW (n = 21)*	*Yoked (n = 21)*
GPA[P]	.45***	.28	.70***	.31	.26*	.23	.42	.12
Prior Knowledge[P]	.34**	.42	.23	.33	.24	.29	.30	.04
Comfort w/ Learning Online	-.27*	-.18	-.47*	-.24	-.09	-.26	-.21	.11
Motivated	.32**	.14	.39	.30	.23	.37	.07	.04
Interested	.41***	.28	.45*	.44*	.37**	.54*	.37	.11
Map's Utility	.27*	.03	.48*	.09	.25*	.31	.29	.01

CW = Clockwise; * $p < .05$, ** $p < .01$, *** $p < .001$
[P] = *Pearson's correlation*, otherwise *Spearman's rho*; Correlation between recall and application scores (all = .60, $p < .001$; free = .54, $p = .01$; clockwise = .76, $p < .001$; yoked = .36, $p = .11$)

Table 13 provides the adjusted means accounting for GPA and prior knowledge, observed mean scores for, standard deviations and confidence intervals for each group on the achievement measures. The means between the three groups appear to be different. The observed means showed that participants with learner control scored on average a point higher than the instructor-sequenced group and two-and-a-half points higher than the group who followed peer-sequenced topics. After adjusting for GPA and prior knowledge, the perceived differences lessened. A MANCOVA with GPA and prior knowledge as covariates revealed no detectable differences between the three groups for either achievement measure: Pillais Trace exact $F(1, 62) = 0.74$, $p = .57$.

Table 13: Achievement measures: mean scores and effect sizes by group.

Cond.*	Recall (Question #1)					Application (Question #2)				
	Adjust. M	*Obs. M*	*SD*	*Low CI*	*Up CI*	*Adjust. M*	*Obs. M*	*SD*	*Low CI*	*Up CI*
Free	9.31	9.83	4.59	7.75	11.92	6.29	6.55	3.60	4.91	8.19
CW	8.98	8.93	4.85	8.81	11.14	6.71	6.67	3.47	5.09	8.25
Yoked	7.67	7.21	3.17	5.77	8.66	6.31	6.10	2.40	5.00	7.19
Effect Size η^2										
Free-CW	.010, p = .54					.005, p = .91				
CW-Yoked	.044, p = .18					.010, p = .54				
Yoked-Free	.104, p = .04					.006, p = .63				

*n = 21/group

2. Were there differences in map utility ratings, recall and application scores between learners who drew a map in response to the recall question and those who did not?

Post-study, I observed that 40% of participants (n = 25) drew a diagram in response to the recall question (n = 7, 9, and 9 for the free, clockwise and yoked groups, respectively). This suggests that these learners may have differed from those who did not draw a diagram. I reasoned that investigating differences in map utility scores and the achievement measures might identify possible map use effects.

Therefore, I computed a new dichotomous variable to examine whether there were differences between the map utility ratings and achievement scores between participants who did or did not draw a map. Non-parametric correlations revealed that this variable was not significantly correlated with self-reported knowledge or regulation of cognition or with the recall or application scores. A Multivariate GLM with the map utility rating and two achievement scores as dependent measures yielded Pillais Trace exact $F(1, 62) = 3.02$, $p = .04$. Univariate tests did not reveal detectable differences for either achievement measure, $p = .53$ and $p = .27$, respectively but rather for the map utility rating, $F(3, 59) = 8.67$ $p = .005$. Not surprisingly, participants who drew a map for their response rated the map's usefulness higher. Implications on the map's use in recall are discussed in the Discussion chapter.

Condition and Metacognitive Awareness Influences: Explorations

This section tentatively examines the data and proposes areas for future consideration, as intended by this research; further, due to the ratio of cases to the number of identified variables, the recorded data is insufficient to make statements that are more definite.

After running correlation analyses between self-reported knowledge of cognition and regulation of cognition scores and the study's dependent variables, *Table 14* shows the relationships. As with Schraw and Dennison's (1994) findings, the two scales were highly related with one another. A positive relationship between knowledge of cognition and learning self-rating suggests that learners who are aware of their strategy use and learning effectiveness self-rated their learning during the study more positively than learners who were less reflective.

As well, the level of self-awareness correlated positively with the recall score, whereas participants' reported ability to control one's learning did not correlate significantly with either achievement measure. Metacognitive awareness as depicted by knowledge and regulation of cognition correlated strongly with learners' post-study motivation self-rating. Learners who reported being more aware of and better able to control their learning also reported themselves to be more motivated; this was particularly the case for the participants who had the most learner control in this study. Motivation to use strategies and to regulate cognition and its related effort may influence SRL and the associated learning outcome (Pintrich & DeGroot, 1990). Whether or not self-reported motivation had an effect on achievement is explored in an upcoming section.

Table 14: Correlations for self-reported knowledge of cognition and regulation of cognition MAI scales and dependent variables.

Variable	Knowledge of Cognition				Regulation of Cognition			
	All (n = 63)	*Free (n = 21)*	*CW (n = 21)*	*Yoked (n = 21)*	*All (n = 63)*	*Free (n = 21)*	*CW (n = 21)*	*Yoked (n = 21)*
How's Learning Rating (ave.)	.35**	.28	.59**	.07	.18	.15	.32	-.07
Recall Score [P]	.26*	.29	-.05	.43	.12	.23	-.13	.21
Application Score [P]	-.01	.11	-.31	.02	-.15	-.03	-.33	-.18
Map Help	.22	.01	.20	.27	.24	.36	-.06	.40
Motivated	.50**	.69***	.41	.24	.39***	.67***	.22	.18
Interested	.08	.16	-.18	.19	.10	.32	-.23	.15

CW = Clockwise; * $p < .05$, ** $p < .01$, *** $p \leq .001$
Correlation between Regulation and Knowledge of Cognition (all .81, free .76, clockwise .73, yoked .75, $p < .001$); *Spearman's rho* unless otherwise stated with [P] (*Pearson's correlation*)

Self-ratings of Learning

To what extent do prior knowledge, metacognitive awareness, personal attributes (interest and motivation), and learner control contribute to learners' average self-rating of their learning over the study period? Personal factors, in addition to treatment group effects may influence learners' experiences during the study. Assuming that self-ratings of learning signified how learning was progressing, determining which factors contribute to the self-rating and by how much, provides a more comprehensive understanding of the learning process. I examined the internal consistency for the seventeen self-ratings of learning through Cronbach's $\alpha = .95$. This indicates that the average inter-item correlation was similar and therefore, computing a scale score from these self-ratings was acceptable. Thus, I computed an average self-rating score from the seventeen self-ratings (one per topic) for this analysis. After computing Spearman's rho for several variables in this study, *Table 15* shows only the detectable relationships between the self-rating of learning and the other variables. Self-reported knowledge of cognition correlated strongly, as did self-reported motivation overall. Lastly, the more time learners spent on studying, the lower their self-rating of learning, which could suggest that learners who spent more time, may have a higher standard.

Table 15: **Correlations for significant relationships between the averaged self-ratings of learning and other variables.**

Variable	Averaged Self-rating of Learning (sum/17)			
	All (n = 63)	*Free* (n = 21)	*Clockwise* (n = 21)	*Yoked* (n = 21)
Prior Knowledge	.22	.17	.41	.08
Knowledge of Cognition	.35**	.28	.59**	.07
Motivated	.42***	.49*	.54*	.27
Total Time Spent Studying	-.31*	-.45*	-.01	-.42
Map Utility Rating	.17	.33	.45*	-.20

Spearman's rho: * $p < .05$, ** $p < .01$, *** $p = .001$

Prior to performing a multiple regression analysis on learners' self-ratings of their learning, assumptions were tested. The standardised scatterplot of the predicted values and residuals, as seen in *Appendix O*, suggests that individual values appear to be normally distributed; the P-P plot also supports this position, as all values appear to be close to the expected values for the regression line (see *Appendix O*). Using $p < .001$ yielding a critical value of $\chi^2 = 24.32$ ($df = 7$) for the Mahalanobis Distance, no outliers among the cases were found.

A stepwise multiple regression investigated the extent to which previous experience, metacognitive awareness, personal attributes, and learner control may contribute to learners' average self-rating of their learning over the study period. Four blocks of independent variables included: (1) GPA and prior knowledge, (2) self-reported knowledge of cognition and regulation of cognition, (3) self-reported levels of interest and motivation, and (4) condition group. Using P-values of .05 and .10 to enter or remove the variables from the model, 27% of the variance was accounted for by the regression model ($R^2 = .27$) and R was statistically different from 0, $F(3, 59) = 7.19$, $p < .001$ (see *Table 16*). Prior knowledge entered into the model in step 1 and accounted for 6% of the variance, while GPA did not enter the model. In step 2, prior knowledge remained when knowledge of cognition entered and added 13% to the variance; regulation of cognition did not enter the model. Lastly, in step three, self-reported motivation accounted for an additional 8% of the variance with the two aforementioned variables. In this step, the model omitted interest. This prediction model suggests that self-reported regulation of cognition had no effect on self-ratings of learning which is consistent with the finding that learner control has no effect.

Table 16: Regression table for predicted (averaged) self-rating of learning.

Step	Variable	b	ß	incre R^2	t	cum R^2	F
1	Prior knowledge	.11	.25	.06	2.03, $p = .047$	.06	4.11, $p = .047$
2	Prior knowledge	.10	.22		1.90, $p = .06$		
	Knowledge of cognition	.01	.36	.13	3.00, $p = .003$	.19	6.97, $p = .002$
3	Prior knowledge	.09	.20		1.74, $p = .09$		
	Knowledge of cognition	.01	.19		1.50, $p = .14$		
	Level of motivation	.24	.33	.08	2.56, $p = .01$	.27	7.27, $p < .001$

Recall Achievement Measure

To what extent do previous experience, metacognitive awareness, personal attributes (interest and motivation), and learner control contribute to learners' scores on the recall measure? The recall measure is presumed to be a product of the studying experience and indicative of learning. The treatment and personal factors may influence the test score and for that reason, identifying possible factors and the extent to which they contribute adds to our understanding of the complexity of learning.

Assumptions were tested by viewing the standardised scatterplot of predicted values and residuals for the recall score and the P-P plot (see *Appendix P*). Both suggest a normal distribution. Using $p < .001$ yielding a critical value of $\chi^2 = 24.32$ ($df = 7$) for the Mahalanobis Distance, no outliers among the cases were found.

To examine the extent to which previous experience, metacognitive awareness, personal attributes, and learner control contribute to learners' scores on the recall measure; four blocks of independent variables entered the stepwise regression analysis: (1) GPA and prior knowledge, (2) self-reported knowledge and regulation of cognition, (3) self-reported interest and motivation, and (4) condition group.

Using p-values of .05 and .10 to enter or remove the variables from the model, the stepwise regression model ($R^2 = .41$) accounted for 41% percent of the variance and R was statistically different from 0, $F(3, 59) = 13.63$, $p < .001$ (see *Table 17*). GPA entered into the model in step one and accounted for 20% of the variance. In step two, prior knowledge entered the model and added 6% to the variance while in the third step, self-reported level of interest added 14% to the model. The variables of interest in this study, specifically knowledge of cognition, regulation of cognition and learner control in map use, appeared to have no detectable contribution to learners recall scores.

Table 17: Regression table for predicted recall score.

Step	Variable	b	ß	incre R^2	t	cum R^2	F
1	GPA	3.40	.45	.20	3.95, $p < .001$	.20	15.22, $p < .001$
2	GPA	3.00	.40		3.54, $p = .001$		
	Prior knowledge	.95	.26	.06	2.27, $p = .027$	.27	10.91, $p < .001$
3	GPA	3.08	.41		4.00, $p < .001$		
	Prior knowledge	.47	.13		1.17, $p = .248$		
	Interest	1.37	.40	.14	3.78, $p < .001$	.41	13.63, $p < .001$

Application Achievement Measure

To what extent do previous experience, metacognitive awareness, personal attributes (interest and motivation) and learner control contribute to learners' scores on the application measure, presuming that the achievement on the application test is a product of the studying experience and indicative of learning? Whether the treatment and personal attributes contribute to the score and to what extent provides a glimpse of influences on learning.

Examining the standardised scatterplot of predicted values and residuals for the application score and the P-P plot (see *Appendix Q)* suggest a normal distribution. Employing $p < .001$ yielding a critical value of $\chi^2 = 24.32$ ($df = 7$) for the Mahalanobis Distance, no outliers among the cases were found. A stepwise multiple regression procedure investigated the extent to which previous experience, metacognitive awareness, personal attributes of interest and motivation, and learner control contribute to learners scores on the application measure. Four blocks of independent variables entered the analysis: (1) GPA and prior knowledge, (2) self-reported knowledge and regulation of cognition, (3) self-reported levels of interest and motivation, and (4) condition group.

Using p-values of .05 and .10 to enter or remove the variables from the model, 23% of the variance was accounted for by the regression model ($R^2 = .23$) and R was statistically different from 0, $F(3, 59) = 8.79$, $p < .001$ (see *Table 18*). Although GPA and self-reported level of interest entered the model in steps 1 and 2, adding 7% and 16% to the variance respectively, the model suggested that neither metacognitive awareness scales nor learner control in map use contributed to predicting the application score.

Table 18: Regression table for predicted application score.

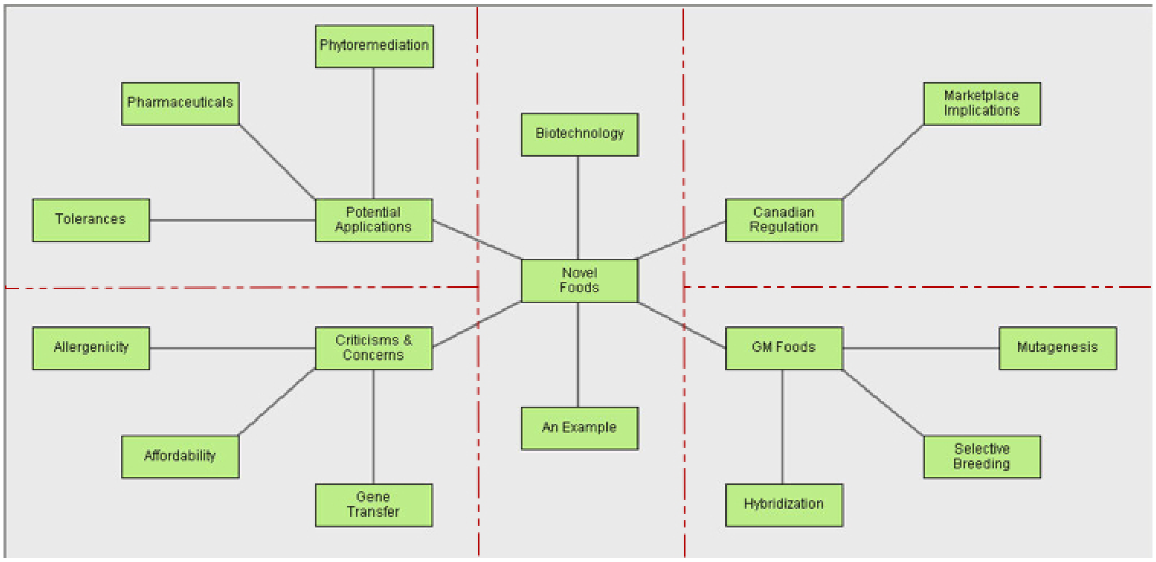
Step	Variable	b	ß	incre R^2	t	cum R^2	F
1	GPA	1.44	.26	.06	2.12, $p = .038$	.06	4.49, $p = .038$
2	GPA	1.34	.25		2.15, $p = .035$		
	Level of interest	1.00	.40	.16	3.50, $p = .001$	.23	8.79, $p < .001$

Topic Selection

Where did learners start, how did they process through the topics, where did they end and what do these findings suggest about learners' studying behaviour? Learners in the free group ($n = 21$) were the only participants empowered to select their own topic sequence. Although the navigational map portrayed a radial hierarchical concept map and I made an effort to determine an instructionally rationalized common navigational path for the clockwise group, there is no standard path. The choices made by learners who had control over their topic sequence, particularly at the start and end topics may offer insight into learners' perceptions of map structures, while the sequence throughout the session may provide a glimpse into the studying process.

Dividing the map in the middle with novel foods, the key topic, appearing in the centre, biotechnology above and an example below, the remaining topics fall within quadrants (see *Figure 15*).

Figure 15: Quadrants and centre areas to define topic selection locations.



Ten (48%) participants selected the centre node, novel foods as their first topic, while one person selected the example, which occurs below the centre node. This suggests that over half of the learners attributed the centre as the starting point. After the centre, the most common topic selection was in the top quadrants. Four (19%) learners selected a topic on far left of the top-left quadrant, while three (14%) began at the top-right quadrant, two (9.5%) at the bottom-right quadrant and one (5%), the bottom left quadrant. No participants started with the top middle topic (biotechnology).

Numbers for the treatment groups were too small to suggest any differences, but I was curious whether there was a relationship between the map's use as an advance organizer and the scores for knowledge and regulation of cognition. Before reading, metacognitive learners tend to examine the text to gain a sense of it such as its structure and sections that may be most applicable to their goals. This helps the learner to plan (Puntambekar & Stylianou, 2005). However, in this study the relationship between the reported scores and map use was not statistically detectable.

Next, I identified and mapped the topic order for each learner in the free group to determine themes and patterns (see *Table 19*). The radial nature of the map appeared to have influenced topic selection for many students since half started from the centre and worked outwards. A systematic progression through the topic-subtopic branches was evident for majority of learners. Furthermore, eight learners altered their topic selection behaviour by accessing the first few topics in no apparent pattern and then changing to a more consistent pattern of working through all topics within a branch before moving onto another branch. This suggested that the learners were aware of their studying experience and made a decision to change.

Table 19: Themes and patterns for topic selection during the study period.

Theme	Pattern
Approach to topic selection	▪ Centre outwards through the branches (11) ▪ Centre out as if map contained concentric circles (2) ▪ A "path" starting from one side of the map to the other, topic selection based on proximity (4) ▪ No identifiable or consistent pattern aside from the proximity of some topics (3) ▪ "Everywhere" (no proximity or pattern) (1)
Change in approach to topic selection	▪ Initial selection by proximity or jumping around, then worked through branches (3) ▪ Did not start from centre, but quickly developed a pattern of working from inner topics through their branches (5) ▪ Generally consistent topic selection behaviour (13)

Use of branches	▪ Topic in the same branch studied consecutively (17). Consistent start with:
	    ▪ A branch's key topic and then sub-topics (16)
	    ▪ A branch's subtopic (1)
	▪ No use of branches for topic selection (4)

Overall map navigation based on quadrants	▪ Complete right side of map then left (13) ▪ Complete left side then right (3) ▪ Alternated sides (1) ▪ Centre (subtopics for novel foods) first (2) ▪ Top then bottom (1) ▪ No pattern (1)
Direction sub-topics of novel foods (inner "circle") were selected	▪ Clockwise (4) ▪ Counter-clockwise (2) ▪ No consistent pattern to accessing sub-topics (15)
Direction sub-topics in branches were selected	▪ Both counter-clockwise and clockwise (13) ▪ Counter-clockwise (3) ▪ Not applicable inconsistent navigation within branches (3) ▪ Not applicable: did not use branches for navigation (2)

*n = 21

For learners permitted to navigate topics as they wished, three inferences emerged from the themes and patterns. First, almost half of the participants (n = 10) started with the centre node, novel foods. Thirteen participants approached topic selection by working from the centre node outwards through the branches or from the centre out in a circle. This suggests that these learners recognized the key concept and that subtopics extended from it. The other learners may have identified this as well, but started elsewhere.

Second, most learners (n = 15) had a discernable pattern in the general approach for how they selected a topic and most participants (n = 13) showed consistent topic selection behaviour from the start, working systematically through the topics (e.g. completing a branch before moving onto another branch, accessing nodes from the centre outwards). Several students demonstrated an awareness of how they were learning by adapting their behaviour as the study period progressed. They started with selecting topics solely on proximity or jumping around and appeared to move toward a more rationalized pattern of working through the branches. This also suggests that learners may not have paid attention to the lines that linked the concepts on the map initially, but did recognize the relationships later and thereby adapted their studying behaviour accordingly.

Third, most students (n = 17) worked through the topics within a branch before moving on to a different area on the map, again suggesting that they recognized a relationship between concepts. Fourth, most learners navigated through the map based on quadrants. More than half of the learners worked through the right side of the map first before moving to concepts on the left side. This differs from the usual left-to-right reading pattern. An explanation may be that the right side of the map had fewer nodes than the left, so learners started with the less complex side. This was a commented by a person in my pilot, but not in the actual study.

In sum, examining the pattern of topic selection suggests that most learners have a systematic approach to selecting and studying topics and recognize the importance of a central node and the relationship among concepts in a branch. Some learners evidently monitored their learning and adapted their approach while studying.

Exploratory Observations on How Learners Study

Due to aforementioned limitations in collecting eye-tracking data, analyses used the complete data (n = 35, 56%) where applicable. Available data per condition group: free (n = 15), clockwise (n = 12), and yoked (n = 8). As a result, eye movement data results reported in this section are exploratory and may serve as a basis for future research.

Investigating Possible Data Bias

Prior to examining differences between groups, possible data bias was investigated. Two concerns emerged (1) whether the distribution across treatment groups differed significantly and (2) whether the participants with and without eye movement data differed on key variables prior to treatment. Assuming that the expected distribution of participants across each group were similar, the expected cell count was n = 11.7. Using this, a Chi-Square test indicated the number of participants with eye movement data was not significantly different across the condition group, χ^2 (2, N = 35) = 2.11, p = .35.

A MANOVA determined whether there were differences among the participants by their treatment group and whether they had eye-tracking data. Dependent variables were GPA, prior knowledge, number of credits completed at the time of the study, age, number of courses with online materials, age the student started using a computer and each of the MAI subscales (declarative knowledge, procedural knowledge, conditional knowledge, planning, information management strategies, monitoring, debugging, and evaluation. The multivariate analysis reflected no differences, Pillais Trace F(1, 62) = 1.03, p = .45, effect size = .24. Based on the multivariate result, I treated the groups as not being different in the proceeding analyses.

Map and Text Use

To recap, the map could have fulfilled five functions: (1) serving as a graphical advance organizer to assist learners with gaining a holistic view of the material prior to studying, (2) providing learners in the free group with a means to select topics and for all learners, a means to navigate through the topics, (2) signalling to all learners which topics they had visited, the current topic being studied and those that they had yet to visit, (4) illustrating the key concepts and their relationships, and (5) offering a point of reference for self-monitoring and review. The focus of this study was on the map. Consequently, the map area was larger than the text area and the text content was deliberately constrained to three sentences. Studying behaviours related to the frequency of observations, fixation frequency and amount of time on both the map and text for each condition group were observable through the LookZone data. Fixation frequencies occur within a LookZone, while observations are transitions across LookZones.

Over a study period, learners' attention may alternate between the map and text. For the purpose of this study, "attention" to the map or text requires *fixations* (focusing for a minimum of .05 seconds). Learners had to observe the map at least twice per topic: once upon arrival to the topic and a second time after reading the text in order to click on the next topic. The text was read at least once, at minimum to rate one's learning and to read instructions for the proceeding topic. Accordingly, the minimum number of times the LookZones could be distinctly observed for the entire study period was 34 (2 x 17 topic pages) for the map and 17 for the text (1 x 17 topic pages).

> H_1: Learners who do not control the topic sequence, but can see a general pattern to the order (*clockwise* group); will spend less time examining the navigational map, compared to the other two groups. Since learners will navigate in a pre-determined clockwise pattern and are unable to select topics, they will not attend to the map as much as the other two groups who require more time with the map in order determine where to go next (free) or how they might have arrived at the current topic (yoked).

Two sets of data defined the level of attention given to the map and text: the first is the fixation frequency. The second, the number of distinct observations for the LookZones where "distinct'' means an occurrence which differs from the preceding observation. For instance, a learner looked at the map and viewed three nodes, then read a portion of the text, looked back at the map to find a term and then continued to read the text: the map and the text each had two distinct observations.

Table 20 denotes the mean fixation frequencies, distinct observations for the map and text, and time for each condition and across all participants with eye movement data. Overall, the data shows that although the map was three times larger than the text space and an important tool for studying, learners made four times more fixations on the text than on the map. The amount of time spent studying the map and text reflected the greater emphasis on the text as well, with learners spending three times more time on the text. Learners also observed the text LookZone more distinct times than they did for the map LookZone.

Group means do not indicate much difference between the number of fixations learners made on the text or the total time spent on the text area. The clockwise group made slightly fewer distinct observations of the text LookZone compared to the other two groups. The yoked group spent 14% of their fixations on the map, compared to 20% by the free and clockwise groups. The yoked group observed the text LookZone slightly more (5.5% more) and spent less time observing the map LookZone (6% less). They also spent a third less time studying the map. Learners who followed peer-sequenced topics were more likely to become lost or confused by this sequence and use the map more to orientate themselves. Despite this opportunity, these learners did not appear to rely on the map to situate themselves within the content or to examine the relationships among the key concepts any more than the other two groups. Similarly, they put more time and effort into studying the text.

An ANOVA and Tukey HSD test examined the means for the total number of fixations on the map and the text, the total number of distinct times participants observed the map and text and the time on each. I did not find detectable differences across the condition groups ($p > .05$).

Table 20: Mean number of fixations, distinct observations and studying time for the map and text.

Variable	Condition	n	Obs. Mean	SD	Lower CI	Upper CI	% of Overall Total	Effect	Size η^2
Total fixations on map	Free	15	309.93	181.31	209.53	410.34	20.98	F-CW	.000
	Clockwise	12	310.83	125.07	231.37	390.30	19.06	CW-Y	.158
	Yoked	8	206.38	123.25	103.34	309.41	13.73	Y-F	.090
	All	35	286.57	153.90	-	-	18.73	-	-
Total fixations on text	Free	15	1,155.73	358.80	957.03	1,354.43	79.65	F-CW	.077
	Clockwise	12	1,331.58	248.03	1,173.99	1,489.17	80.99	CW-Y	.009
	Yoked	8	1,276.63	353.74	980.89	1,572.36	86.30	Y-F	.028
	All	35	1,243.66	324.15	-	-	81.27	-	-
Total number distinct times map LookZone observed	Free	15	172.87	89.09	123.53	222.21	46.94	F-CW	.096
	Clockwise	12	130.24	52.23	97.06	163.43	46.51	CW-Y	.111
	Yoked	8	120.19	38.72	87.82	152.57	39.57	Y-F	.171*
	All	35	146.21	70.87	-	-	45.23	-	-
Total number distinct times text LookZone observed	Free	15	195.38	109.41	134.80	255.97	53.06	F-CW	.067
	Clockwise	12	149.76	52.29	116.53	182.98	53.49	CW-Y	.093
	Yoked	8	183.57	67.47	127.17	239.97	60.43	Y-F	.003
	All	35	177.04	70.87	-	-	54.77	-	-
Total time studying map: seconds*	Free	15	138.92	104.80	80.88	196.95	21.16	F-CW	.016
	Clockwise	12	117.97	44.35	89.80	146.15	19.16	CW-Y	.147
	Yoked	8	79.52	52.81	35.37	123.66	12.15	Y-F	.096
	All	35	118.16	79.21	-	-	20.29	-	-
Total time studying text: seconds*	Free	15	440.29	123.61	371.84	508.74	69.88	F-CW	.032
	Clockwise	12	484.11	124.04	405.30	562.92	77.70	CW-Y	.000
	Yoked	8	478.63	174.89	332.42	624.85	73.52	Y-F	.018
	All	35	464.08	134.19	-	-	73.71	-	-

* The sum of the total percentage of time studying the map and text do not equate to 100% above as time can be spent outside of the LookZones, and other variances may be due to the subject's gaze not being fixated or short term tracking loss by the equipment; F = free, CW = clockwise, Y = yoked; * $p = .05$

Map Fixations: Relationships and Patterns

Recall that at the end of the Method chapter, levels of map fixation activity were identified on a scale of 0 to 3, ranging from no activity (beyond using the map to pick a topic to navigate to), to viewing most or all nodes intently. The purpose of this data was to examine the extent to which learners study the map at different stages of the study period. Learners employed the map in multiple ways depending on the point in time. Use at the start may have been as an advance overview to gain a sense of the content. While learners studied, the map may have provided them with an overall sense of the studied topics, current topic and remaining study topics. It served as means of navigation or topic selection and could have played a role (1) in knowledge construction where the learner could refer to the map in order to connect the active concept with others, and (2) in monitoring comprehension and studying pace. The map's use at the end of the study session may have assisted review.

As the study session progressed, learners' use of the map may have varied. To determine this, I identified the varying levels of map use (described in the Method section) and the number of learners per treatment group for each level (see *Table 21*). Half of the clockwise group (n = 6) studied the map intently at the start while only one person in each of the other groups viewed the entire map at start. As the session progressed, learners made less use of the map to the point of looking at only a couple of topics or merely for navigation. On the last page, half of the participants across all groups did not review the map at all. The yoked group either reviewed the entire map (n = 2) or not at all (n = 6) whereas there was more of a distribution within the other two groups with the bulk. Only a third of the participants viewed the entire map or the majority of it intently inferring that these students engaged in review prior to ending the study session. I calculated Kendall's tau-b to examine the strength of the association between the degree of map use and treatment group for each of the different points in the studying process. Results suggest that degree of association between the treatments and map use was not statistically detectable.

Table 21: Map use during different points in the studying process by condition.

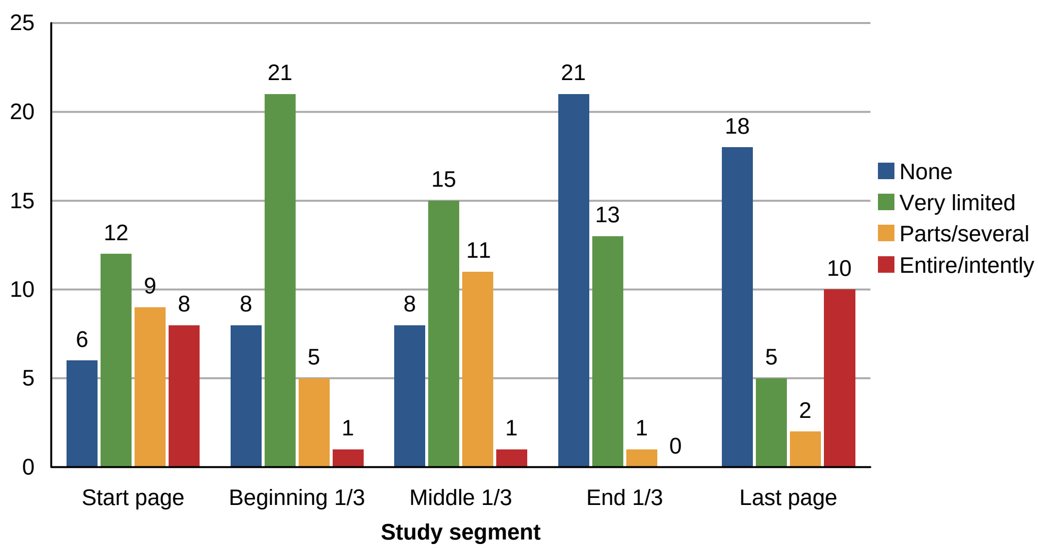
Variable	Degree of Map Use	Number of Participants				Kendall's tau-b	
		All (n = 35)	*Free (n = 15)*	*CW (n = 12)*	*Yoked (n = 8)*	*Value*	*Approx. Sig*
Start page						.114	.44
	None beyond navigating	6	4	0	2		
	Very limited	12	5	4	3		
	Viewed parts/several topics	9	5	2	2		
	Viewed entire map/intently	8	1	6	1		
Beginning 1/3						-.094	.50
	None beyond navigating	8	3	2	3		
	Very limited	21	10	6	5		
	Viewed parts/several topics	5	2	3	0		
	Viewed entire map/intently	1	0	1	0		
Middle 1/3						-.204	.145
	None beyond navigating	8	2	4	2		
	Very limited	15	6	5	4		
	Viewed parts/several topics	11	6	3	2		
	Viewed entire map/intently	1	1	0	0		
End 1/3						-.166	.28
	None beyond navigating	21	8	7	6		
	Very limited	13	6	5	2		
	Viewed parts/several topics	1	1	0	0		
	Viewed entire map/intently	0	0	0	0		
End page						-.054	.72
	None beyond navigating	18	7	5	6		
	Very limited	5	4	1	0		
	Viewed parts/several topics	2	1	1	0		
	Viewed entire map/intently	10	3	5	2		

CW = Clockwise

A relationship between achievement scores and studying the map was predicted since the latter provided an overview of key concepts and their relationships, which was then testable via the achievement measures. Additionally, a relationship between the extent to which learners studied the map and their knowledge and/or regulation of cognition scores on the MAI was expected. Learners who reported being metacognitively aware might value and use the map more for its multiple functions. However, non-parametric correlation coefficients (Kendall's tau-b and Spearman's rho) failed to suggest any statistically detectable associations between the extent to which the map was studied at the start, three points during studying, and at the end of the study period with the achievement and cognition measures ($p > .05$, 1-tailed). The data suggest possible patterns of studying behaviour however.

As seen in *Figure 16*, half to two-thirds of learners examined the map in a very limited manner or not at all throughout the study period. This was particularly evident for the last set of pages. At the start, learners varied in whether they studied the map or not, but by the end of the study time, half of participants did not examine the map while about a third studied the map in its entirely or the majority of parts intently. Viewing the map in its entirety was observed for the start and end pages, but scarcely for the bulk of the studying period. As time went by, fewer learners viewed the map aside from using it as a navigational tool.

Figure 16: Levels of map use at different times while studying.



Overall Fixations

The eye-tracking data may provide further insight into the general process of studying. *Table 22* shows that in the 10-minute study period, learners fixated an average of 1,525 times. The study time for the 35 participants with eye-tracking data, was M = 638.11 seconds (SD = 163.41). Compared to the average time participants were not fixated, the data suggests that learners were not fixated 19.03% of the time. The data also showed that participants' average fixation duration was .32 seconds (320 *ms*), supporting previous eye movement research that found fixations to occur between 50 and 500 *ms* and close to the average of 200-250 *ms* estimated by Rayner et al. (2005).

Table 22: **Descriptive data for the number of fixations, time not fixated and average fixation duration by condition group.**

Variable	Condition	n	Mean	SD	Lower CI	Upper CI	Effect	Size η^2
Total fixations during the study period	Free	15	1,454.53	397.12	1,234.62	1,674.45	F-CW	.076
	Clockwise	12	1,641.58	242.61	1,487.44	1,795.73	CW-Y	.061
	Yoked	8	1,482.50	415.60	1,135.05	1,829.95	Y-F	.001
	All	35	1,525.06	356.30	-	-	-	-
Total time not fixated (seconds)	Free	15	117.19	45.44	92.03	142.35	F-CW	.005
	Clockwise	12	123.17	39.16	98.29	148.06	CW-Y	.002
	Yoked	8	126.76	42.07	91.59	161.94	Y-F	.011
	All	35	121.43	41.55	-	-	-	-
Average fixation duration (seconds)	Free	15	.34	.06	.30	.37	F-CW	.090
	Clockwise	12	.30	.04	.28	.33	CW-Y	.025
	Yoked	8	.32	.08	.25	.39	Y-F	.009
	All	35	.32	.06	-	-	-	-

* F = free; CW = clockwise; Y = yoked

Learners' Self-reported Studying Experiences

Data for the following analyses were collected from all participants (n = 63).

Motivation and Interest

Did levels of motivation and interest differ between the treatment groups? Motivation and interest are associated with learner control and proposed to influence achievement (Ainley & Hidi, 2002). For that reason, examining learners' reported levels of motivation and interest contributes to an understanding of the learning process. As well, learners' reported motivation and interest levels may be examined with eye movement data, open-ended responses, and test scores, thereby possibly illustrating relationships between the treatment, studying behaviour, self-reports and achievement.

Table 23 lists the detectable relationships between self-ratings of motivation and interest and the independent and dependent variables in this study. At the end of the study session, learners reported on their levels of motivation and interest while studying. The relationship between the self-ratings was detectable overall and for the free and yoked groups, supporting to the notion that interest is a motivational construct (Alexander & Jetton, 2003). It also appears that learners who were more metacognitively aware were also more motivated. For the topic of novel foods, participants with prior knowledge indicated that they were more interested in the topic. Overall, the more motivated and interested learners reported being, the more they found the map to be useful and the better their score on the recall task. The interest self-rating was positively associated with the application score. Finally, learners who reported that they were motivated also self-rated their learning to be better.

Table 23: Spearman's rho correlations for self-reported motivation and interest

Variable	Motivated				Interested			
	All *(n = 63)*	***Free*** *(n = 21)*	***CW*** *(n = 21)*	***Yoked*** *(n = 21)*	***All*** *(n = 63)*	***Free*** *(n = 21)*	***CW*** *(n = 21)*	***Yoked*** *(n = 21)*
GPA	.29*	.50*	.43	-.18	.05	.18	.30	-.32
Know. of Cognition	.50***	.69***	.41	.24	.08	.16	-.18	.19
Reg. of Cognition	.39***	.67***	.22	.18	.10	.32	-.23	.15
Prior Knowledge	.15	-.04	.31	.20	.33**	.34	.40	.29
Map Help	.29*	.39	.23	.15	.39**	.42	.19	.51*
Recall Score	.32*	.14	.39	.30	.41***	.28	.45*	.43*
Application Score	.23	.37	.07	.04	.37**	.54*	.37	.11
How's Learning Rating (ave.)	.42***	.49*	.54*	.27	.18	.15	.42	.22

CW = Clockwise; * $p < .05$, ** $p < .01$, *** $p \leq .001$
Correlation between motivation and interest (all .36, $p = .004$; free .48, $p = .03$; clockwise .18, $p = .61$; yoked .51, $p = .02$)

Motivation and interest scores did not differ much across the three groups. On average, participants self-rated themselves a little higher than mid-point on the 0 to 5 scale. The yoked group reported being slightly less motivated and interested than the other two groups, while the free group was the most motivated and the clockwise group was the most interested. A MANOVA tested group differences in motivation and interest. The test indicated that group assignment effects were not statistically detectable, Pillais Trace exact $F(1, 62) = 1.37$, $p = .25$, effect size = .04. The univariate tests identified no differences. Generally participants self-rated their level of motivation and interest slightly higher than the mid-point on a scale from 1 to 5 ($M = 3.62$, $SD = .73$ and $M = 3.38$, $SD = 1.26$).

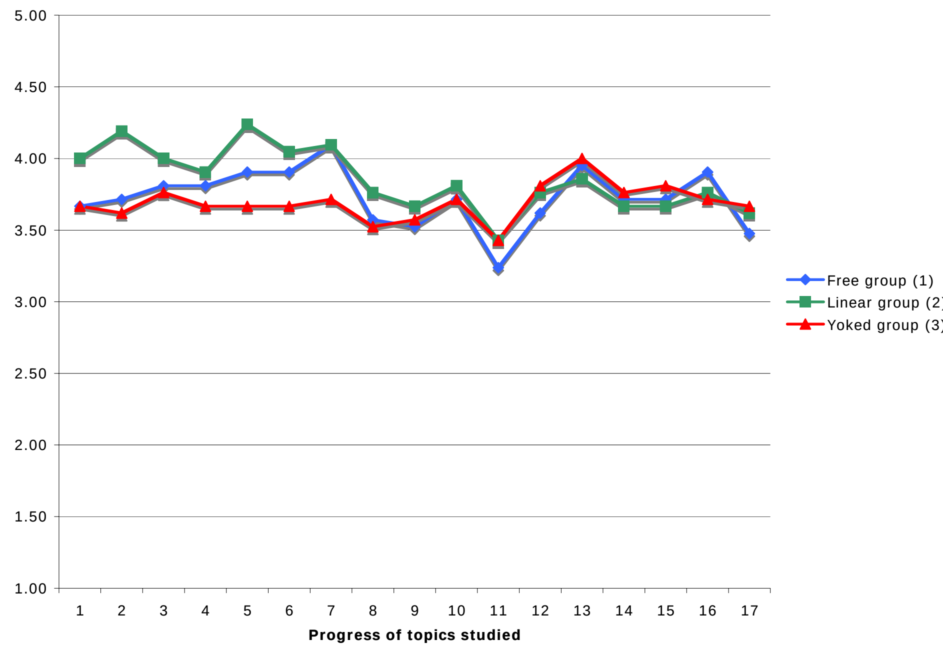
Table 24: Motivation and interest self-ratings: mean scores, standard deviations and confidence intervals by group.

Condition	Motivated				Interested			
	M	*SD*	*Lower CI*	*Upper CI*	*M*	*SD*	*Lower CI*	*Upper CI*
Free	3.76	.83	3.38	4.14	3.24	1.26	2.66	3.81
Clockwise	3.67	.58	3.40	3.93	3.76	1.18	3.23	4.30
Yoked	3.43	.75	3.09	3.77	3.14	1.32	2.54	3.74
Effect Size η^2								
Free-CW	.005, $p = .67$				.046, $p = .17$			
CW-Yoked	.032, $p = .25$				.061, $p = .17$			
Yoked-Free	.045, $p = .18$				.001, $p = .81$			

Self-rating of Learning

Over the study period, did self-ratings of learning change? Self-ratings of learning may reflect learners' perceptions about their learning at that particular point in time. Plotting the mean self-ratings per topic studied illustrates patterns that emerged for the treatment group. *Figure 17* illustrates the mean self-ratings per group over the study period. Self-ratings appeared to be consistent and similar for the three groups. About two-thirds into the studying period (topic 11), a sudden dip appears where learners in the three groups provided their lowest self-rating which was then followed by a higher self-rating for the next topic. Participants in the clockwise group studied the same topic at that point (gene transfer) suggesting difficulties with the content that may have in turn, resulted in a lower self-rating. This was not the case for the free and yoked groups because their 11th topic varied. Therefore, this fluctuation for the one self-rating may be due to chance.

Figure 17: Self-rating of learning over the study period.



* 5=very good, 4=good, 3=acceptable, 2=poor, 1=very poor

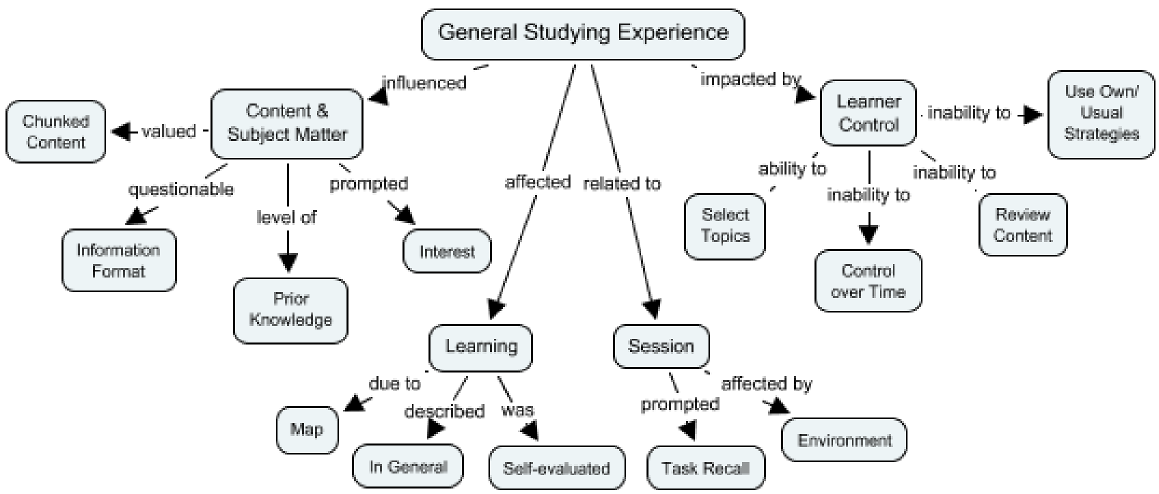
Themes, Streams and Patterns

What may we observe as themes, streams and patterns from students' descriptions of their studying experience and what did they find to be easy and challenging? Insight into the learners' experience through their feedback may complement and support the quantitative data acquired from the eye-tracker and achievement tests. Focused on "studying" and not the entire experimental process, questions were intentionally generic to allow learners to express their key sentiments. The following subsections describe the themes, streams (within the themes) and patterns from the open-ended questions with notable treatment group differences where applicable. Unless otherwise stated, numbers associated with statements signify ideas and not the number of participants. For example, a participant responds with three comments that fit into one stream. The number "3" associated with that stream represents the statements and does not mean that three people made a comment. Numbers in parentheses are participants' ID numbers.

General Studying Experience

"In one or two sentences, describe your studying experience" (see *Appendix R* for categorized verbatim responses). *Figure 18* identifies the themes and streams derived for the participants' responses.

Figure 18: General studying experience themes and streams.



Focusing on the content and subject matter, the first theme contained four streams: chunking of content, questionable information format, prior knowledge and interest. Two learners (one each from the free and clockwise groups) valued the chunked content. Meanwhile the content's length and quantity were issues as observed through nine negative comments and two learners questioned the map's logic and the topics' level of importance. Difficulties arising from too much information within the study materials (participants did not differentiate between the map and text) resulted in being overwhelmed and difficulties with planning and self-pacing. The content also negatively affected information management and made strategy implementation more challenging for the learners. Nine learners acknowledged the level of prior knowledge they had about the subject matter with seven statements declaring a lack of familiarity and two stating some knowledge. Interest in the topic was the final stream. Through nine statements: five of which were from the yoked group, learners noted a positive learning experience because they found the topic interesting.

The second theme revolved around learning: related to the map in general and self-reflection about approaches to studying. Participants made twenty statements specifically about learning with the map. Seventeen were positive, were relatively evenly distributed across the treatment groups, and emphasized the map's usefulness in making studying easier and more enjoyable through its organization. One neutral statement from a learner in the yoked condition expressed an "overall midrange of ease of use" (312) while one learner in each of the free and yoked groups expressed negative sentiments related to the format of the map noting eye-strain from looking "all over the screen" (114) and an expectation for a more linear style.

The remaining streams relate to more general and self-evaluative comments. Participants made positive statements about the learning experience through eighteen statements such as, "it is good to learn something in a short period of time" (108), "finding out about my learning retention, it was great!" (210), and "I found my studying experience to be very enlightening"(306). Learners expressed five relatively neutral statements about their studying experience and fifteen negative statements. The clockwise group's only negative comment was a lack of interactivity, while five learners in the free condition commented on general difficulties and nine learners in the yoked condition reported challenges with recall and feeling pressured. Aside from general challenges, some participants' remarks consisted of recalling one's own behaviour during the study period and for some, insights: "I read everything over once, but I should have read it twice" (113), "I realized that I have to consider my time when doing certain tasks" (221), and "I did not pay attention to the image" (303). These unsolicited comments suggested that learners actively engaged in the evaluation component of self-regulation.

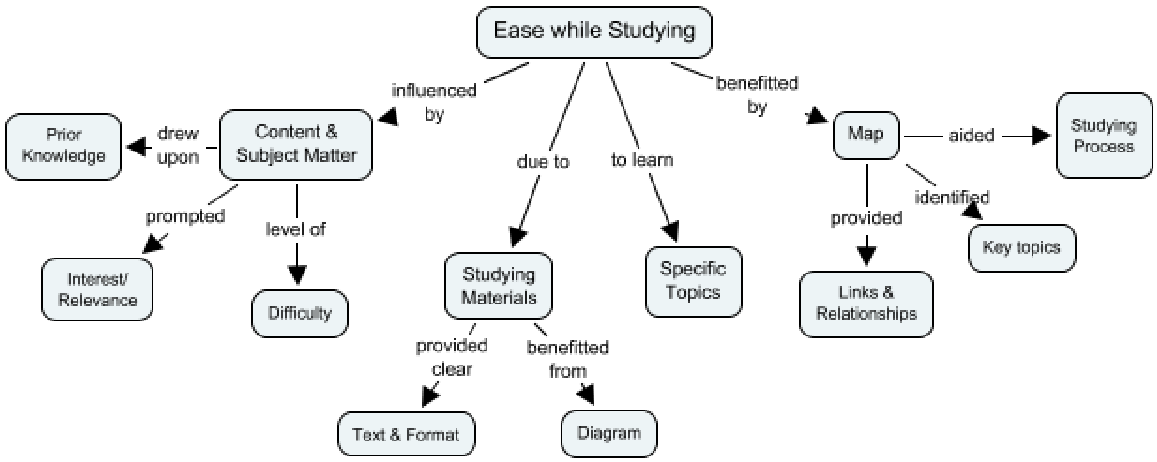
The third theme focused on the studying session's tasks and environment. Some learners recalled their tasks without qualifying the experience. This occurred in five statements, such as "My studying experience involved reading text, viewing diagrams, and answering questions" (310). However, participants made their thoughts about the environment and implicit effect on studying through two positive and four negative comments (e.g. "it was kind of easy for me to forget that I was in a monitored environment so the process felt natural" (317) and "was not in ideal conditions" (121)).

The final theme revolved around learners' level of control. Only two positive comments emerged from the 26 remarks: Two participants in the free group appreciated having choice and the ability to select topics. Whereas the remaining statements expressed frustration over a lack of control over the time available to study and its related pressures (nine statements across all three groups) and the restrictions imposed on navigation, namely the lack of ability to go back to previously read topics (four statements). Learners appeared to be aware of this constraint and its impact on self-regulation: particularly monitoring and debugging. As well, participants made pointed statements in the last theme concerning the inability to implement one's own learning strategies and how the studying process differed from desired or usual studying methods (free = 2, clockwise and yoked = 5 each). Statements included, "I can't use my own studying methods when in this environment" (107), "...different as I am usually taking notes on the side to help me remember key facts" (208), and "For me, making the breakdown myself it [sic] usually where half my learning comes from" (311). Conditional knowledge underlie the twelve statements; learners seem to be aware of the strategies they normally used and why.

What Learners Found Easy

"While you were studying, what did you find easy?" The broad question aimed to capture any aspect of the studying experience for which the learners wanted to report (see *Appendix S* for detailed results). *Figure 19* illustrates the themes and streams for the question.

Figure 19: What was easy while studying? Themes and streams.



The first theme centred on the content or topic. The first stream consisted of fourteen comments about having prior knowledge, where learners reported that having some prior knowledge made studying easier, helped learners to know what to expect, and enabled connecting new knowledge with their prior knowledge. Sample statements included, "I had some background on the topic I was reading so I could relate more easily and therefore understand the topic more" (217). Four remarks about having personal interest in the topic and the topic's relevancy formed the next stream, while the final stream incorporated eight statement fragments about the content's level of difficulty. For instance, one participant remarked, "The information that was presented was not very challenging to grasp" (109).

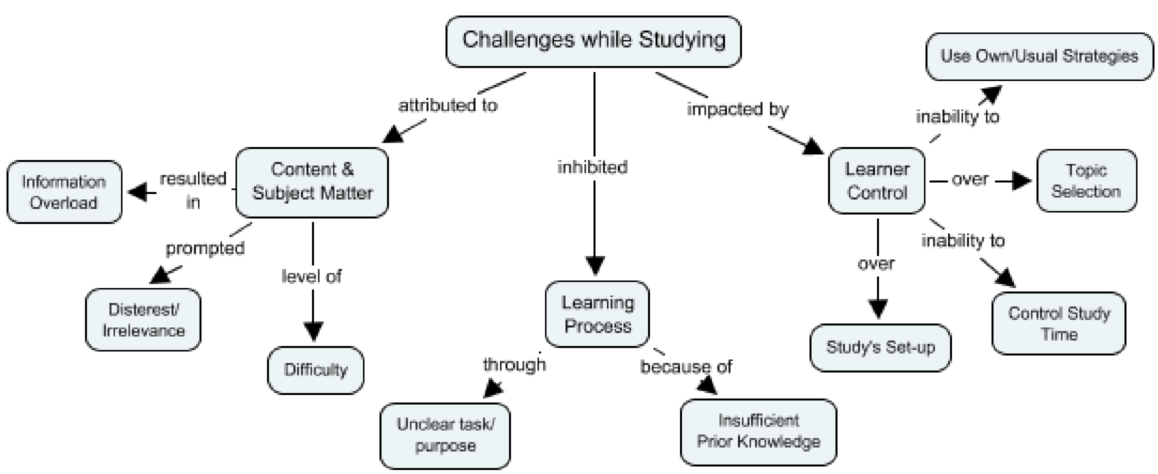
The second and third themes continue to emphasize the studying materials. The second theme focused on benefits resulting from general format of the studying materials. Eleven learners noted that short sentences, concise text, and an easy to understand layout aided their learning. Meanwhile five learners indicated that the diagram was beneficial. A participant in the yoked group made only one of the sixteen statements under this theme. The third theme and its ten statements referred to specific topics within the studied content. Participants identified terms and ideas that they found to be easier to remember and understand, in particular higher-level nodes that grouped sub-topics (e.g. criticisms or applications) and non-technical terms.

Learner's abilities and accomplishments resulting from map use while studying formed the final theme. Through eight comments, learners noted how easy it was to identify links or relationships (e.g. "I found the diagram to be quite helpful because it showed the relationship between the topics I was studying", 216). Similarly, participants made six statements about how easy it was to identify the topics. While a learner in the yoked group made the only comment about knowing one's location, "I can keep track of where I am in this study" (316), six learners remarked on how easy it was to navigate between topics. The free and yoked group each provided three of these statements. The last stream related to the process of studying with three comments from the clockwise group and two from the yoked group (i.e." I found the points towards the end easer to study, as I developed an understanding of how the material was laid out" (205). As evidenced in this last theme, learners saw value in using the map to facilitate their learning and the studying process.

What Learners Found Challenging

"While you were studying, what did you find challenging?" *Appendix T* contains detailed remarks on studying challenges while this section and *Figure 20* describes three identified themes related to the content, learner control and studying process.

Figure 20: What was challenging while studying? Themes and streams.



As described in the previous section, learners identified the content and subject matter as being important. In this case, it posed challenges as described in three streams. Eight learners noted problems with information overload and retention. Remarks included, "there was too much information that I…had to think hard about, in most of the sentences" (106), while five learners revealed disinterest in the topic or a lack of relevancy, "the topic is not really of my interest, so it is a little unmotivating [sic] to keep going to me" (321). One learner expressed concerns about the content's level of difficulty and its related effect, "Reading complicated sentence structure or words slowed me down, causing me to read and reread sentences" (314). To sum, learners reported that the content and subject matter had negative effects on learning, some related to individual differences such as motivation and interest.

In the second theme, participants identified challenges with the studying process, which they believe affected learning. Three statements from two participants demonstrated a lack of understanding about the purpose of the task, what was to be tested or how: "I did not know what the goal of studying the material was" (205) and "…I had no idea what kind of questions were ahead – would I have to define things?" (317). Prior to studying, learners read through instructions, which stated, "Study all the topics to prepare for a subsequent test which consists of two questions: 1. Recall everything you remember, including key concepts and their relationships and 2. Apply what you have learned to a given scenario". Even though the instructions asked participants not to proceed with studying until they were ready, it appears that these two learners missed the instructions and lacked specific learning goals a result. One of the learners, who received the instructor-sequenced treatment, was the twelfth highest scorer on the recall question and the twenty-fifth on the application question. The other learner received the peer-sequenced treatment and placed forty-fifth on the recall question and twenty-first on the application question. Overall, the participants appeared to have compensated for their lack of knowledge about the task.

Learners faced further challenges as evidenced by fifteen comments on insufficient prior knowledge and eight statements on difficulties with remembering terms, facts and topics. The new concepts and terminology (1) inhibited a learner's ability to relate them to previously learned information and (2) were more difficult to memorize and process because of they were complex and lacked meaning to the learner: for example, "I only really learned the examples and not the academic terms" (114). One learner evaluated his own studying behaviour, noting that he had difficulties with keeping a slower pace because he had prior knowledge of the topic.

Several streams formed the learner control theme: control over the study's set-up, time, topic selection and use of learning strategies. Three learners attributed challenges to the study's set-up where they were tested right after studying, had to self-rate their learning for every page, and used an old computer monitor. An additional eight comments identified the 10-minute studying period as constraining. Participants in the free and yoked groups made five statements about control over navigation and choice. The former conveyed a desire for direction and remarked how deciding where to go was challenging, while learners in the yoked group perceived the topic order to be scrambled and wanted the ability to choose their own topics. Fourteen statements centred on a lack of control over learning strategy use: three concerning the inability to take notes and eleven noting restricted navigation and an inability to review. Some learners reported on the impact this had on their self-regulatory processes, namely monitoring and debugging. "If I had been able to go back to the previously studied topic I would have been able to relate topics better" (101) and "wasn't able to go back to a topic in order to draw connections between it and something I just had finished reading" (302).

The Utility of the Navigational Map

Were there differences in the reported utility rating of the navigational map by condition group, in particular between the yoked and free groups? Participants were asked, "How *useful* was the map as a study aid?" and to respond on a scale of 0 = not at all, to 5 = extremely. If learner control over topic navigation mattered, then I expected lower utility ratings for the yoked group because the map would have less meaning for these learners since they lacked the ability to navigate. Most research reported attitudes that are more favourable from learners who experienced learner control (Williams 1996). If simply knowing one's location within the content was sufficient, then I anticipated similar ratings across the three groups. If having some instructional guidance through the topics was beneficial, I expected then higher ratings by the clockwise group. Lastly, the clockwise group may also demonstrate higher ratings if self-directed or peer-directed navigation was challenging to the other two groups.

Table 25 lists the counts for each group. The majority of participants reported that the map was useful while they studied, with one third indicating that it was extremely useful. The yoked group's ratings imply that they found the map to be slightly less useful than the other two groups. An ANOVA and Tukey HSD tests for the map utility rating determined no detectable differences across the condition groups: $F(2, 60) = 2.08$, $p = .13$ for the ANOVA and $p = .99$ (free – clockwise), $p = .17$ (free – yoked) and $p = .21$ (yoked – clockwise) for the Tukey HSD tests.

Table 25: **Map utility counts, mean and standard deviation by treatment group.**

Condition	Map Utility Rating								Effect	Size
	0 (not at all)	*1*	*2*	*3*	*4*	*5 (extremely)*	*Mean*	*SD*		η^2
Free	0	0	2	4	7	8	4.00	1.00	F-CW	.001
Clockwise	0	0	2	4	8	7	3.95	.97	CW-Y	.059
Yoked	1	2	2	6	4	6	3.33	1.49	Y-F	.067
All	1	2	6	14	19	21	-	-		

* n = 21/group

Was there a relationship between a person's rating and the extent to which they used the map at the start and end of the study period? I observed the cross-tabulations for the map utility score and the level of eye fixation activity on the start page and the final page. Kendall's tau-b and Spearman's rho correlation coefficients for the map utility rating and level of fixation activity at the two study points examined the relationship more closely.

As seen in *Table 26*, a detectable relationship emerged, for the last page. The post-study rating on the map's usefulness appeared to reflect one's perceptions about the map at the end of the study period.

Table 26: Map utility ratings at different points in the studying process.

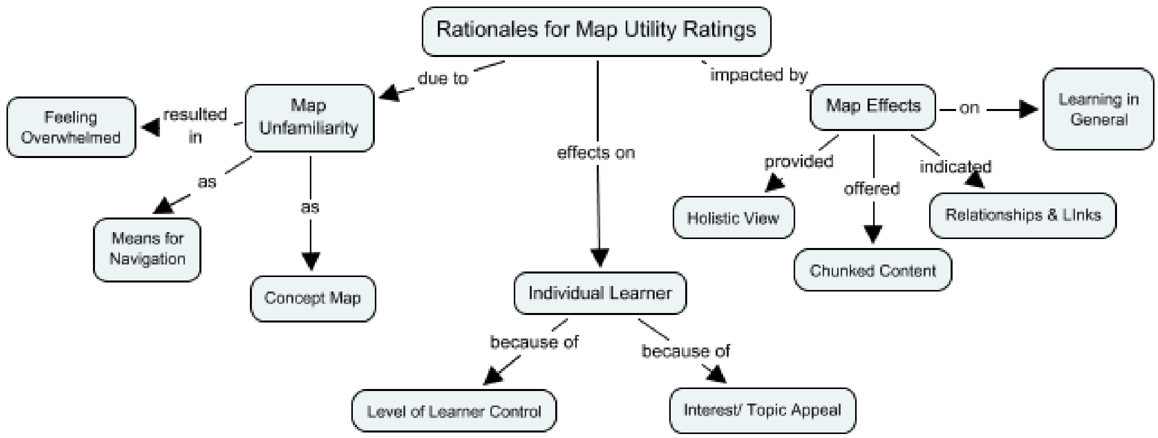
Study Point	Kendall's tau-b			Spearman's rho		
	Value	*Approx. T*	*Approx. Sig*	*Value*	*Approx. T*	*Approx. Sig*
Start page	.09	.60	.55	.09	.52	.61
End page	.47	4.33	.00*	.54	3.67	.001*

After having examined the map utility ratings, what were the main themes, streams and patterns for the reported rationales for the map utility ratings?

Rationales for Map Utility Ratings

What explanations do learners provide for their utility ratings? Learners' feedback on map utility may help to explain learners' recorded studying behaviour, achievement scores and treatment effects. Related rationales, identification of strengths, weaknesses and suggested improvements may provide guidelines for future iterations of similar maps. *Appendix U* provides detailed responses to, "Given your rating in #1 [map's usefulness], explain why." Three themes emerged as illustrated in *Figure 21*.

Figure 21: Rationales for map utility ratings: themes and streams.



The first theme was a lack of familiarity with the map's format, which resulted in feeling overwhelmed. The map's functions as the means for navigation and as a concept map were also new to some learners. The six statements about the format of the study material noted that the map was somewhat overwhelming compared to the usual use of an outline or chapters and sections, problems with the placement of the materials, and initial confusion. This lack of familiarity likely resulted in extraneous load, pulling cognitive resources away from actual learning. One participant in each of the clockwise and yoked groups commented about their confusion and time needed due to use the map as a means of navigation for pre-determined topics. Three participants in the yoked group stated explicitly that they did not pay attention to the map as a concept map, but merely used it to navigate to the next topic, suggesting that these learners did not find the map's identification of key concepts and relationships useful for their learning.

The second theme focused on map effects on the individual learner. Learners made positive or negative remarks to form the learner control and interest or appeal streams. Two learners in the free condition stated that the ability to choose the topics was positive, while two other learners had difficulties with the choice by not knowing where to start and go. Two learners in the yoked condition also reported negative sentiments about the map because the navigation did not seem to flow and were unable to choose a starting point. Related to interest or appeal, five comments were made that the map lacked visual appeal while three mentioned how the map drew interest by allowing the learner to pick topics (free participant), kept their interest ("I think without it, I would of switched off a while ago", 210), and provided a good visual.

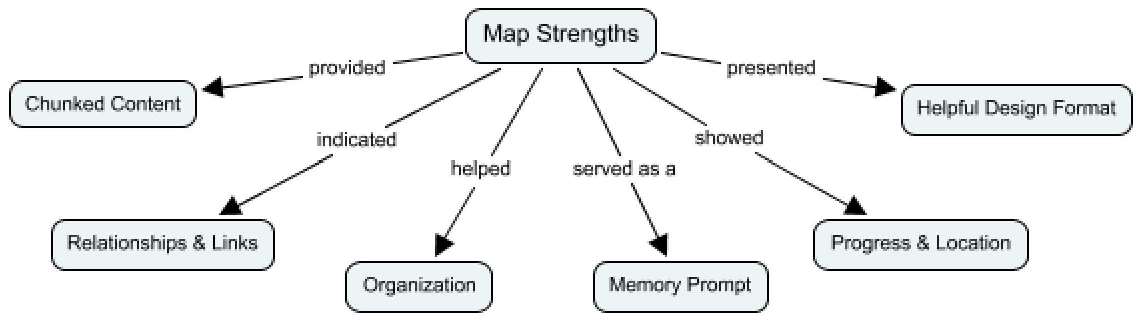
The third theme encompassed map effects, which for the most part facilitated the learning process. Eight learners asserted that the map provided a holistic view which resulted in positive effects on learning such as enabling the learner "to grasp the concept as a whole" (103), to see the whole picture of what was to be learned, connect with the topic, and to gain a general overview of the topic at the beginning. Ten statements about the positive effects of the chunked content formed the second theme. Learners reported several map effects on the learning process including: aiding organization, providing a "physical layout to fall back on when trying to remember", breaking down the information into manageable units for studying and recall, and prompting recall of the relationships among concepts due to chunking.

In addition to chunking, the map also indicated links and relationships. From the twenty-nine statements in this stream, twenty-six statements cited positive effects. The ease of identifying connections between topics and groupings enabled learners to make connections for later recall, helped to visualize the topics, and build in previously learned, related topics. Meanwhile, three learners (two in the yoked condition and one in the clockwise group) declared difficulties with the links. They explained that the connections between the terms were difficult to find and contained too many branches, which negatively affected their recall or learners ignored altogether to focus on the terminology within the allotted time. The final stream noted the map's effects on learning in general. Seven learners identified themselves as visual learners and that the map aided this type of learning, while other learners who found that the map did not fit with their learning style or preferences made seven remarks to that effect. Eleven learners identified the map as a potentially effective learning aid while three learners found it to be ineffective. Four statements stated that the map provided direction on where to go and three learners in the free group noted that the map clearly signalled whether or not learners had studied the topics. In this case, the map not only served as a means for navigation, but as a gauge during the studying process.

Map Strengths

Appendix V lists the responses to, "What were the map's *strengths* in helping you to study?" As seen in *Figure 21* many of the themes are duplicates of themes and streams identified in learners' rationales for map utility ratings.

Figure 22: Map strengths: themes and streams.

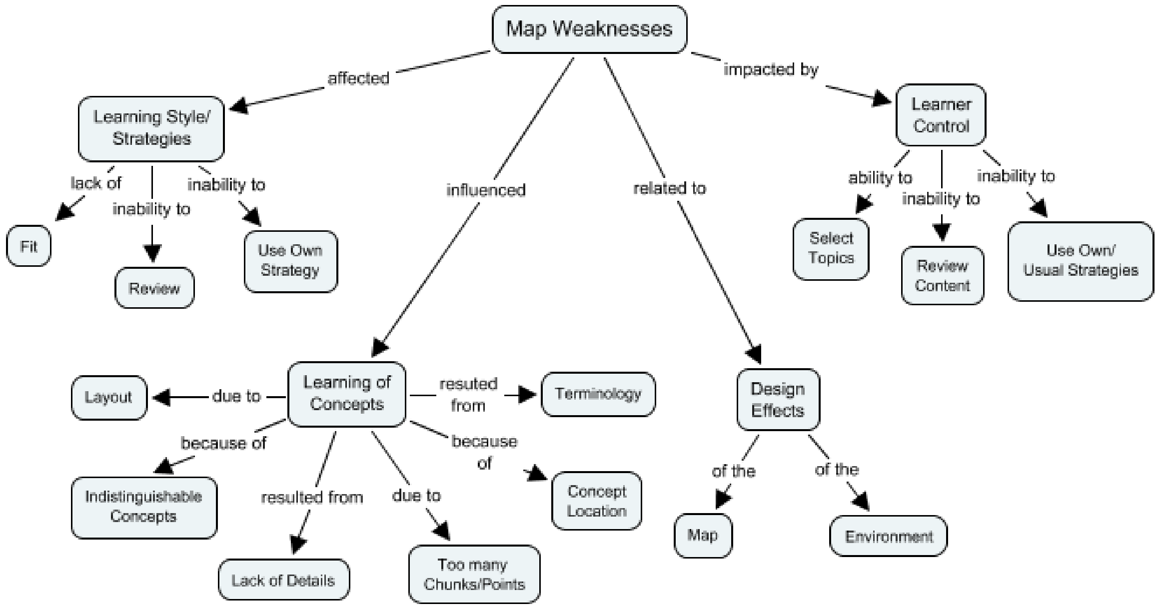


Seven statements mentioned the advantages of chunked content, while twenty-five statements noted how the map showed links and relationships. Two learners found that the map's overall structure provided a holistic view, while twelve noted that the provided organization to the content on the screen and conceptually. Learners explained how remembering one concept led to linking it to more in the same branch and how the map signalled a new topic, which then aided the organization of topics in the learner's mind. Seven statements described how the map served as a prompt by providing a mental map, was used a tool to identify how well material was understood, and aided recall through its visual depiction and links. Six learners appreciated that the map showed one's progress and location while studying. Finally, participants made four statements about the usefulness of the map's format: the alignment of boxes, use of colours, and spider-web or flow chart format aided learning and memorizing. Many of the points related to the map's strengths repeated responses to the other questions.

Map Weaknesses

Appendix W tables the responses to the question, "What were the map's *weaknesses* in helping you to study?" and *Figure 23* illustrates the themes and streams.

Figure 23: Map weaknesses: themes and streams.



The first theme focused on the maps effect on learning styles or strategies. Three learners noted that the map's use did not fit with their learning style. Ten learners described how the map's restricted navigation prevented them from reviewing content while studying which negatively affected recall and the ability to create connections between topics. One learner noted that she was unable to enact one of her commonly used study strategies: creating a map, because the map was pre-made.

The second theme described the map's effect on learning the concepts due to its layout, distinguishable concepts, details, chunks, location of concepts and terminology. Five learners noted that the map made it difficult to get the overall picture due to a lack of details or challenges with the layout. Three learners found that the concepts were not distinguishable enough, that additional colours or ways of identifying levels would have been helpful. Eight learners, four each in the clockwise and yoked groups found the map to lack necessary details or to be too simplistic, while eight other learners described the map as being complicated with too many chunks or points, which made remembering difficult. Four statements pertained to issues about the location of concepts, where a learner remembered the positioning, but could not recall the concepts while the other three questioned the categorizing of topics. Finally, six statements reflected difficulties with the terminology: technical terms were difficult to remember, did not completely disclose what the text paragraph was about or were difficult to connect.

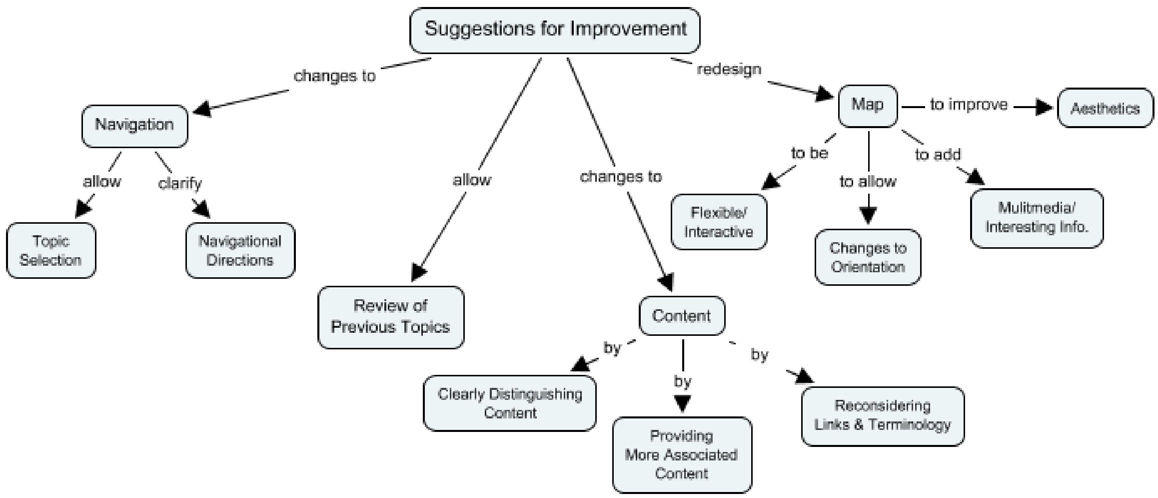
The third theme concerns design of both the map and the study environment. For the map stream, five comments related to map aesthetics, three on how the map was distracting, affected deep thinking and one's ability to focus on the text, and one remark about its use as a navigational tool. In terms of the environment, one learner noted that looking at the computer resulted in sore eyes and two learners were distracted by having to self-rate their learning before moving on to the next topic. The task to gauge and report one's learning seems to have disrupted the learning flow for these learners.

The last notable theme related to control over topic selection, review and use one's own learning strategies. Topic select challenges varied depending on the treatment group. Only one person in the clockwise group noted that the map did not allow movement to desired topics, while five learners in the yoked group felt constrained by the lack of control. In some cases, the seemingly illogical flow made it difficult to follow and remember the topics. On the other hand, five learners in the free group stated that having navigational control was difficult: they did not know where to start, where to go, and if a particular order was preferred. The ability to review and reread previously accessed topics was another important stream for ten learners (five each from the free and clockwise groups).

Suggestions for the Map

Appendix X identifies learners' *"Suggestions* to improve the map so that it is more helpful for studying". Four themes emerged as outlined in *Figure 24*.

Figure 24: Suggestions for map improvements: themes and streams.



Four themes capture learners' suggestions for improving the map. The first recommended changes to navigation. Two learners in the yoked group suggested allowing learners to choose their topics, while five statements suggested improvements to navigational directions using arrows, a non-radial approach, and colour or embedding links within the text rather than using the map for navigation. A second theme related to the ability to review. Nine learners recommended allowing learners to go back and review previous topics. Interestingly, these suggestions did not come from the yoked group.

In the third theme, participants suggested changes to the content or more specifically, terminology. Thirteen statements prescribed distinguishing the content further using colour, formatting, font size, or numbering. Eighteen comments suggested providing more associated content in the form of definitions, layers, links to more information, labels on connections, summaries, tool-tips, diagrams beside details to serve as another cue, and examples. The final stream advised reconsidering the links and terminology. Four statements indicated rearrangements to the branches while another four suggested eliminating scientific terms and making the topics clearer.

The final theme focused on the map's overall design. Two learners suggested making the maps more flexible or interactive so that learners can adjust the format to their liking, while nine learners recommended changing the map's format to a hierarchical or linear map, several maps, or a vertical orientation. Six of these learners were participants from the yoked group. Four learners noted that interest might increase if the content designer added sounds, images or additional interesting information. Lastly, five learners recommended improvements in the map's aesthetics (e.g. font, size, colour and layout).

Comments on Studying Experience and Navigable Map Use by Treatment

Using the data in *Appendices Q* to *W*, I categorized participants' comments by treatment group to capture the essence of the learners' studying experience and map use. *Table 27* identifies the comments (left column) and suggestions (right column) participants in the three treatment groups made about their general studying experience. A dichotomy existed for many of the responses whereby one group of learners found an aspect of the studying experience positive and another group responded negatively to the same component. Several comments revolved around prior knowledge and interest: these individual characteristics have been noted in previous research as well as in the present study to play a detectable part of one's learning experience. Remembering the content was challenging for many students and more so for the peer-controlled sequence group. Many statements concerned the content. The groups varied little in their comments. All suggestions requested improvements to the information presented in the map or the text.

As mentioned earlier, the map could have served several roles in this study: as an advance organizer, navigational tool, pathway indicator, actual material-to-be-learned, as well as a means to monitor and review both while studying and at the end of the study period. Two of these categories merged with others in *Table 28* to form three categories, because comments did not clearly fall within a particular function. Overall comments about the map varied little across the groups as well. However, the instructional and peer-controlled sequence group made almost double the number of positive comments the learner-controlled group made about the map's usefulness in identifying the links among the concepts. Noteworthy were comments about the amount of control over topic sequence that differed across the groups. Although the learner control group made some positive comments about having control over the topic sequence, there was double the number of negative comments. The peer-controlled group also made several negative comments about their level of sequence control. Since the instructor-controlled sequence group only made one negative comment, this data suggests that full control and no control combined with a lack of meaning to the order of the topics are undesirable.

Table 27: Studying experiences and suggestions for improvement by group.

Comment	Free		Clockwise		Yoked	
	Note	Sug.	Note	Sug.	Note	Sug.
Instructions: easy to understand			1		1	
Instructions: not clear			2		1	
Content: short & to the point	1		1			
Provide more content		5		7		6
Content too long/a lot: difficult/overwhelming/terminology	8		5	1	1	3
Content level of difficulty: easy	1		4		5	
Content: specific content easy	4		2		4	
Questioned relevance/logic of details			2		2	
Low prior knowledge (neutral/negative)	10		7		5	
Had prior knowledge (positive/neutral)	6		5		5	
Had Individual interest/relevance	3		3		7	
Lacked individual interest/relevance (topic)	3		0		1	
Lacked situational interest (resulting from the study)					1	
Add components to improve situational interest		1		2		1
Lacked motivation					1	
Studying environment/task was distracting	1					
No control over time	3		7		7	
Issues with the text's format	1	1				
Learning in general: positive (interesting experience, fun, enjoyed)	6		6		6	
Learning in general: neutral	3		1		1	
Learning in general: negative (difficulties)	5		1		6	
Difficulties remembering	6		7		11	
Forgetting to rate learning	3					
Environment: positive	1		1		1	
Environment: negative	3		0		2	
Participant described the tasks	2		2		1	
Total comments about the general learning experience	70	7	57	10	69	10

* Note = comments derived from all open-ended questions except for suggestions for the map. Sug. = suggestions for improving the map

Table 28: Map experiences and suggestions for improvement by condition group.

Category	Issue	Free		Clockwise		Yoked	
		Note	Sug.	Note	Sug.	Note	Sug.
Advance Organizer & Material to be Learned	Provided a holistic view of the content	2		3		5	
	Difficult to get overall picture from the map	1		1		3	
	Useful chunking/grouping of topics	9		9		4	
	Too many chunks/points	2		2		4	
	Useful to identify links/relationships	14		23		23	
	Difficulties with links (e.g. not clear, too many)		2	1	2	3	
	Provided organization for learning	4		5		3	
	Useful for identifying key topics	4		2		4	
Subtotal of comments		36	2	46	2	49	0
Pathway Indicator and Navigational Tool	Aided in monitoring his/her location	5		3		2	
	Provided direction through the links	3	2		1	1	2
	Did not like navigating using the map			1		2	2
	Only used the map for navigation					3	
	Topic sequence: having control was positive	4					
	Topic sequence: level of control was negative	9		1		10	
Subtotal of comments		21	2	5	1	18	4
Affected Learning Strategies	Led to self-reflection of approach to studying	1		6		4	
	Prevented from reviewing previous topics	12	5	9	4	4	
	Unable to implement own learning strategies	4		6		6	
	Fit with learning style: visual learner	3		3		1	
	Did not fit with participant's learning style	1		2	1	7	1
	Easy to remember content: visual/memory aid	4		2		3	
Subtotal of comments		25	5	28	5	25	1
Learning with the Map: General or Indirect Effects	Map instilled interest	1		1		1	
	Map was distracting			1		2	
	Learning with map: positive/had potential	8		11		9	
	Learning with map: neutral					1	
	Learning with map: negative	3		2		2	
	Map format was easy to use	5		5		1	
	Useful visual	4		4		1	
	Components not distinguishable enough	2	7		3	1	7
	Missing visual aids					1	
	Unfamiliar format	1	1	3	2	2	6
	Lacked appeal	3	3	6	1	2	1
	Lacked details (simplistic)	0		4		4	
Subtotal of comments		27	11	37	6	27	14
Total comments about the map		**109**	**20**	**116**	**14**	**119**	**19**

* Comments derived from all open-ended questions except for suggestions for the map. Sug. = suggestions for improving the map

Global Themes

Across the open-ended response questions, common themes appeared. This section identifies the global interrelated themes and sets the stage for explanations and implications in the Discussion chapter. The first theme was the study's effects on self-regulation. The study's design negatively affected some participants' use of learning strategies and their general approach to studying. They reported an inability to use their usual review strategy because of the restricted navigation, as well as note taking and breaking down the topics themselves. The time constraint felt rushed to learners who usually take more time to read and study and challenged several learners on pacing. Other comments indicated that environmental factors were not ideal, which affected some learners' concentration.

These remarks suggest that the study sessions unfamiliar process and the map's unconventional format may have imposed additional cognitive load. The disorientation resulting from a lack of *system knowledge* resulted in frustration that could have affected system use and task persistence (Hill & Hannafin, 1997). System knowledge consists of one's prior knowledge and experience with a particular information system or at least a similar one. High system knowledge enables learners' strategic use of system features, while low system knowledge results in learners' lack of awareness on how to improve processes and make the most use of features (Hill & Hannafin). Several learners appeared to be metacognisant by explicitly evaluating their studying and remarking on what they could have done better. These learners reflected on how the map and studying process differed from their desired or usual studying methods and the challenges they faced as a result.

The map itself also influenced self-regulation as evidenced through many comments. The questions that asked participants about their general studying experience and what they found easy did not refer to the map. Yet several participants responded in relation to map and its impact on studying and learning. Learners noted that the map helped to organize information and chunked it in a manner that was easier to digest, depicted the content visually and holistically, and served as a mental map at the start and throughout the study period for some participants. Learners reported that the map helped them to develop or call upon an existing mental representation and establish connections between terms. This supported one of the expected functions of the map and observations by Langan-Fox et al. (2006).

Although the map depicted the active, visited and unvisited concepts, only a couple of participants commented on how the map enabled them to situate themselves within the content and to monitor their progress. Meanwhile learners made several remarks on how the map facilitated the identification and, in some cases, recall of key topics and their relationships. A few participants noted that they were visual learners and therefore, the map appealed to their learning style and made studying easier. Unfamiliarity with the map posed challenges for a few learners causing them to spend more time and effort on using the map than studying the content, a problem also noted by several researchers (e.g. Hartley & Bendixen, 2003, Schwartz et al., 2004).

Individual differences emerged as a second global theme. As noted earlier, learners' level of prior knowledge and interest may affect their self-regulation (Alexander, 1995). Prior knowledge, a critical factor in learning from hypertext (Niederhauser & Shapiro, 2003) appeared as a topic in responses across all of the open-ended questions. Learners remarked about their level of prior knowledge and its effects on learning, generally citing ease when they already had some knowledge in the general topic, with the exception of one participant who had problems with pacing because he had prior knowledge. Learners expressed difficulties with the amount of content and the terminology when they had low or no prior knowledge. Participants also commented on the content's fit or connections with their previous knowledge: aware of an existing mental representation, they described whether they could build on it. Prior knowledge also affects interest and Kintch (1980) as cited in Schraw et al, (2001) put forward that moderate levels of knowledge may increase interest and learning while low or high prior knowledge may decrease interest.

Perceived interest emerged as a second component of the individual differences global theme. This appeared to play an important part on learners' level of engagement, effort and self-regulation as participants made explicit comments about its effects. The learners described interest in terms of individual interest (pre-existing in the domain) and situational interest arising from the topic itself, the type of information provided (facts, examples) or interest as a result of the map, which prompted engagement and motivated some participants to study. Situational and individual interest overlap and result in the state of interest that is linked to increased attention, cognitive processing, task persistence and influences affect (Hidi, 2001). Associated with interest was personal relevance. Learners reported that their level of interest depended on whether they found novel foods to be a personally relevant topic.

The study restricted the ability to review and study time to 10-minutes for all three groups, while topic selection was not available for two groups. Participants identified all of these as issues. Hence, the impact of learner control forms the third global theme even though it is related to the other themes. Participants expressed dismay over the inability to review previously read material, noted that it had a negative impact on learning because they were unable to make connections between new and previous concepts, build on previous material, or confirm details. Limitations on review also restricted the extent to which learners could engage in monitoring and adapting. When asked for suggestions to improve the map, many participants advocated for future maps to allow students to review.

Several learners commented on the effects of the 10-minute study session, indicating that they normally take their time to read or re-read, but felt pressured during the study. The lack of control may have placed an additional task on learners to manage their time since all participants completed the study session. Therefore, the lack of learner control may have mitigated their skills to self-regulate as well as reduced their sense of having choice. Choice increases interest by allowing learners to select topics they enjoy or are curious about, to opt for familiar learning materials and control over the studying process, all of which increase intrinsic motivation and likely engagement (Schraw et al., 2001).

In terms control over topic sequence, also related to choice, a few participants in the free and yoked groups desired a different level of control. Although learner control over decisions is posited to prompt increased feelings of competency, more meaningful learning, intrinsic interest, and more active learning (Maier, 2002), learners who navigated freely lacked direction and experienced stress not knowing where to start, where to go or the most appropriate direction. This is consistent with Vekiri's (2002) observation and Williams' (1996) who cited several studies concluding that learners with control over instructional elements were unaware of how to manage their own learning environment or lacked the appropriate skills. These learners did not appear to benefit from having control over topic selection. A few participants in free group mentioned that they valued being able to choose their topic path since the coherency made it easier to remember the content. Some participants in the yoked group wanted to control the topic sequence particularly since the order the topics appeared did not make sense to them. The lack of meaning to the order of the topic presentation made it difficult to make connections between topics. In some cases, learners stated that they did not pay attention to the map aside from using it as a navigational tool. These comments indicate that the peer-ordered sequence was irrelevant, disorientating, and did not meet their learning goals and some learners adapted by minimizing the map's use.

The final global theme concerned the learning materials: the content, topic and their design. For almost every aspect: content chunking, content presentation, terminology, difficulty, quantity, level of detail and available links, learners made negative and positive remarks and within each, statements appeared to be on a continuum. For example, comments about the content's difficulty ranged from being too easy to too difficult. Similarly, the amount of information presented opposing challenges for learners. For some, there was not enough detail, whereas for others, there was too much information.

The terminology used in the map, which also served as the navigational link, was unfamiliar and meaningless for some learners. Similar to a study by Mobrand and Spyridakis (2007), expectations were not met when perceptions of the explicit wording were not as positive as they had expected. In their study, the researchers expected that the explicit wording group would explore more than the generic wording group, but results did not show this. The researchers attributed learners' discouraged exploration to their confusion about the hyperlinks. In the present study however, the unfamiliar terms likely affected the formation of connections between concepts and learning at the global level.

Moreover, half of these negative feedback statements clearly indicated that the map was too simplistic or lacked necessary details while the other half stated that that it was too complicated with too many chunks or points to remember. Learners frequently proposed further distinguishing the content and map in some manner, such as using colour, which may facilitate chunking and enable parallel search by unifying same-coloured items and enabling learners to ignore the others (Lohse, 1997). This theme suggests that learners vary not only on individual characteristics such as prior knowledge and interest, but also on how content presentation can meet individual needs and personal preferences. Finding the right balance between challenging the learner and ensuring enough system cohesion is difficult, especially since the balance varies across learners (Shapiro, 1998).

The Discussion chapter brings these results together with those found in other sections of this chapter and examines them in light of the study's hypotheses and the existing literature. The open-ended responses provided insight into participants' learning experience with the map that would not otherwise know. Learners acknowledged the five roles of the navigable concept map and expressed a general sentiment that the map's format helped their learning, although future designers could improve on the aesthetics and functionality to optimize studying conditions. The map fulfilled a concept map role, presenting key topics, links and relationships in a holistic illustration.

Many learners were aware of their learning strategies and processes and the effect individual differences and the map had on learning and self-regulation. The map aided learners with organizing the content by providing a framework to build upon. It also served a self-regulating tool, enabling learners to review the concepts and relationships, prompting recall and enabling monitoring of their level of understanding. However in many cases, the text appeared to be more important to learners as evidenced by comments about inability to review (the map was always there to review). The map benefited some learners by indicating their progress and location within the content, again helping with pacing and self-monitoring. However, the ability to select topics and navigate using the maps did not appear to be valued. Although I had intended for the embedded navigation to strengthen learners' connections between the topics, this did not seem to occur since comments related to this function expressed unfamiliarity with this means of navigation and in some cases negative effects. A few learners valued the map's functionality, which enabled learners in the free group to select their topics, but it posed challenges for others. Although learners varied on the extent to which topic selection and guidance was desirable, participants frequently stated that learner control over time and the ability to review was critical for learning.

At this point, before moving onto the Discussion chapter, readers interested in a sample learner profile that brings together data collected for this study may appreciate *Appendix Y* where I describe "Nikki", her studying experience, selected path through the topics, and make use of the abundance of eye movement data (fixation sequence, scanpath). The section documents Nikki's scanpath, including initial and reviewed topic LookZones, viewing patterns, observations and time spent on LookZones per page. Proceeded by an account of her studying experience, scores on the achievement measures and suggested implications.

CHAPTER V: DISCUSSION

Hypermedia has the potential to offer flexible learning opportunities for students, and as creating media like navigable concept maps is becoming easier, its use is more prevalent. Although research exists on organizers, including comparisons between different print-based organizers and more recently investigations on online organizers, research on applying specific types of maps, distinguishing among their properties (Langan-Fox et al., 2000), and determining appropriate levels of learner control is relatively new. Research on navigable maps use with learner control is also inconclusive, requires more substantiated evidence on how learners may employ them while studying and has offered limited cognitive explanations.

This study aimed to examine navigable concept maps with different levels of learner control and their effects on studying and achievement; to investigate the relationship between metacognitive awareness, self-regulated learning, individual differences and studying and achievement; and to explore learners' studying experience and the studying process. Starting with a recap about the learners in the study, the proceeding two sections provide highlights and explanations about the findings. Then, following a more general discussion of the contributions and implications of this study, a section speaks to the study's limitations, flaws, and considerations. The chapter concludes with suggested future research directions and next steps based on the preceding implications and limitations sections.

The Learner: Pre-study

Demographic data suggested a trend where the younger the participant, the younger they were likely to have been when they had their first experience with a computer. Participants use the internet frequently: daily if not several times a day. Students experience more online learning material as they progress through their academic career. However, irrespective of the increasing opportunities, about eighty-five percent of the participants in this study reported no self-perceived gains from learning online compared to print materials, with only one tenth reporting learning better with online materials. This suggests that learners may not be benefiting from the full potential of hypermedia that hypermedia may not actually be as beneficial as expected, or that online materials require improvements.

The distribution of scores on the Metacognitive Awareness Inventory (MAI) subscales leans towards the upper end of the scale. The self-reports may be inaccurate due to overconfidence in self-judgments similar to that found by researchers such as Jamieson-Noel and Winne (2003) or due to social desirability bias, a tendency to present one's self in a positive light (Reber & Reber, 2001). Correlations between GPA, a relatively stable measure of performance, and self-reported knowledge and regulation of cognition measures demonstrated a moderate positive relationship, suggesting that there is some merit to the MAI responses since one's perceived metacognitive skills are positively related to achievement (Kauffman, 2004). Meanwhile there was negative correlation between age and the MAI subscales. Older students may be more realistic in their self-reports or are more experienced and thereby able to provide a more accurate rating, as proposed by Gagné and Glaser (1987) who observed that metacognitive abilities are present in mature learners, as an executive control processor.

Map Functions and Effects on Studying

Learners could have employed the navigable concept map in five ways: as an advance organizer, a navigational tool, a pathway indicator, actual material-to-be-learned, as well as a means to monitor and review while studying and at the end of the study period. All of these functions are interrelated. To address practical and theoretical considerations holistically, I have framed these functions within the studying process.

Prior to Studying

At the onset of a study task, learners need to establish an internal representation of the subject matter (Winne & Hadwin, 1998). The navigable concept map in this study was constructed to show content and structure in a clear manner through a hierarchical, albeit radially displayed structure and to support the identified learning goal: to learn the key concepts and their relationships. An overview of the information presented in a clear hierarchical manner was postulated to aid recall and comprehension (Schwartz et al., 2004; Shapiro, 2005). The map was a type of signal that was proposed to prompt learners to shift from processing the information as a "temporally organized list to be memorized", to focusing on the hierarchical and conceptual structure of the subject matter and therefore gain a more holistic notion of the text (Kardash & Noel, 2000, p. 318).

The first screen shown to learners during the study period consisted of the map at the top with no content to be studied in the bottom text area thereby allowing learners to focus on the map if they so choose. Since the initial stages of self-regulation entail task definition, goal setting and planning (Winne & Hadwin, 1998), metacognitive learners tend to examine a given text before studying (Puntambekar & Stylianou, 2005). Therefore, one would expect that learners would spend some time examining the map to gain a sense of the topics they will study and to plan their learning strategy. For the learner control group, seeing the connections and number of topics may help learners to decide on their navigational approach and to set a plan for direction and pacing. Flexibility in sequencing may enable learners to organize content in a manner that fits best with their existing cognitive structures (Maier, 2002). In other words, the navigable concept map could have served as a graphic advance organizer, either instilling a mental framework for learners to build on, or to call upon prior knowledge and enable connections with the image.

However, as Kloster and Winne (1989) remarked, the effectiveness of graphic advance organizers benefit students only if they use them effectively. In this study, most learners did not take the time to examine the concept map prior to studying and fully exploit its potential. Surprisingly, as evidenced from the eye-tracking data, only 23% of the 35 learners examined the map in its entirety or intently at the start, 17% did not look at it all, and the rest viewed only limited parts. Although graphic overviews have been found to be effective for learning concepts and their relationships with one another (Robinson & Kiewra, 1995), very few learners acknowledged the map's potential role in preparing them for the studying activity as evidenced by the map's lack of use. For learners who did study the map intently upon starting the session, their reasons are unknown. In their post-studying responses, learners did not make any explicit statements about how the map prepared them for learning the content or how it was useful at the start. Correlations between the map's use as an advance organizer and participants' perceived knowledge of cognition or regulation of cognition scores were not detectable. The use of the map prior to studying was not related to participants' views of their metacognitive skill as measured by the MAI.

While Studying

Some map functions overlap or are difficult to identify. For example, without a real-time explanation of intent while studying, it was difficult to identify when learners used the map as an organizer or material-to-be learned. Therefore, I have combined some of the functions in this section.

Navigation, Topic Selection and Sequence

Disorientation increases the time learners take to find information and causes them to progress through the content sub-optimally (McDonald & Stevenson, 1998). Navigating through text may also interfere with a student's ability to cognitively process the content (Niederhauser & Shapiro, 2003). The navigable concept map in this study indicated the visited, current, and unvisited topics and provided the means for navigating within the online environment. Learners accessed information for another topic by clicking on its topic label on the map. The purpose of embedding navigation within the map was to contextualize the concepts, to enable learners to see how the concept they were studying related to the other concepts and to reduce cognitive load, particularly for the learner control group who had the added responsibility of deciding on topic order (Williams, 1996).

I observed each learner as he or she studied and did not see any challenges with using the map as a navigational tool. However, a participant from each of the clockwise and yoked groups remarked in their responses to the open-ended questions that they found the navigation time-consuming and confusing. Participants in these groups received a pre-defined topic sequence and at the end of the text passage, received instructions to select a specific topic from the map. Then participants shifted their attention to the map to search for and select the next topic. Although Langan-Fox et al., (2000) noted that exposure to the conceptual model of the system helps students to make connections, the learners' remarks about the process suggests that they did not perceive the value of the dual-purpose of the map.

In this study, learners set their own pace when moving between topics within the given study time and were required to work through all topics before ending the session. The free group experienced additional learner control in terms of topic selection and sequencing. Data on the learner controlled group's topic selections indicated that the map influenced half of the learners in their approach to topic selection as they worked from the centre out through the branches. Topic selection was generally consistent for most learners, while a few learners evidently developed a pattern after some self-assessment. Most of the learners studied topics in the same branch before moving on. These patterns suggest that most learners were aware of the links between the topics and chose where to navigate because of the links. One of the strengths of a navigable concept map is illustrating concepts and their relationships (Puntambekar & Goldstein, 2007). The map in the present study met this function, at least in terms of navigation for the learner control group.

An Organizer and Material-to-be-learned

Learners had the opportunity to use the map as a graphic organizer throughout the session. It presented a concrete representation of the information, which learners might use to organize information. Moreover, it was the only means provided to see and learn about the key topics and their relationships. Results showed that learners tended not to view the map in its entirety as studying progressed. Rather, when learners viewed the map, they generally looked at the concepts nearest the one they were currently studying or around the topic that they ended up clicking on. The effects of the map on organizing and learning the material were most often reported as being positive, but a minority of students reported negative effects.

For those with positive reports, learners felt that the map provided a holistic view of the content. When learners encode maps as holistic units, the map features and structural connections are available together, thus making it easier for learners to produce and maintain mental images of maps (Vekiri, 2002). The map's ineffectiveness for these learners appears to be related to low prior knowledge as evidenced by their scores. As well, learners may have been unaware of how the map might improve efforts to learn, and how to better approach learning using the map (Hill & Hannafin, 1997).

Although a few comments stated there were too many chunks or points, more learners stated that chunking made learning the content easier. This supported Lohse's (1997) assertion that chunking can increase information acquisition by freeing working memory capacity when concepts and relations are coded into higher order links. Gestalt principles (connectedness & proximity) contend that grouped or connected information is likely to be perceived as interrelated and their relationships inferred rather than needing further processing to identify these relationships (Vekiri, 2002).

Furthermore, a few learners in each group indicated that the map was useful for identifying key topics and helped to organize their learning. Although a handful of comments indicated that the links were not clear or the learner did not attend to the links, the most frequently commended function was the map's usefulness in identifying links or relationships among concepts. There were sixty idea units to this effect. Inexplicably the learner control group made half the number of comments compared to each of the other two groups. One possibility may be Tergan's (1997, cited by Eckhardt et al., 2003) observation that learners tend to look for ideas through pre-existing links rather than linking concepts on their own. In this case, the learner control group may have just followed the links between concepts more when selecting topics or paid less attention to them than the other two groups and therefore, made less comments about them.

The navigable concept map took up two-thirds of the screen, while the text area consisted of only a few lines visible at the bottom of the screen. The purpose was to emphasize the map and de-emphasized the text because concept maps are encoded more spatially than linear adjunct displays. Therefore, it had the potential to augment learners' use of their working memory by processing visual and verbal information concurrently (Robinson et al., 1999). Almost half of the participants drew in response to the recall question, suggesting that the learners employed the map while studying and as a means for recalling the topics and their connections.

Despite the prominence given to the map in this study as material-to-be-learned and its potential use as an advance organizer, learners did not pay as much attention to the map as a source of information-to-be-learned as I had expected. Learners made more fixations and distinct observations and spent more time studying the text, possibly reflecting people's tendency to attend to text because of their previous experience and better skills with text (Langan-Fox et al., 2006). More than half of the thirty-five participants used the map solely for navigation or in relatively limited ways; however, the text effects were notable in the achievement measures. Learners responded more frequently with information from the text rather than with terms or connections identified in the map.

Remarks about the simple nature of the map suggested that it did not fulfil its role in reflecting the conceptual structure of the domain. Puntambekar et al., (2003) suggest that the real strength of hypermedia lies in its ability to present concepts, their numerous and multiple interrelations, and to further express logical relationships between concepts. This level of detail was not present in this study. Moreover, Wade (2001) noted that a lack of coherence and the use of difficult vocabulary negatively affect comprehension and interest. Wade reported complaints about choppy, disjointed, not well-organized or poorly flowing text, and too many unfamiliar terms. In this study, there were a few similar comments, suggesting that the design may have negatively affected comprehension and interest for some participants. In fact, three participants in the yoked group reported that they only used the map as a means of navigation, revealing that these learners did not value the map's role as a concept map and material-to-be-learned.

Monitoring and Review

Learners may have employed the map for monitoring and review. The monitoring and review functions are closely related to the map's roles as a navigational aid and material-to-be-learned. Whether learners review parts of the map or the map in its entirety, return to look at the map or alternate between the map and text during the study period, these actions demonstrate efforts to connect new knowledge with prior learning or the development of a mental model. Self-monitoring affects the learning process considerably, but requires learners' effort to generate, process and act upon this information (Deimann & Keller, 2006). Given the number of distinct times learners viewed the map and text LookZones, (depending on the group, 2-3 times more than what was needed to navigate) some review had occurred. Even though learners could not review the text, the map was available to monitor one's understanding of the topic. Self-monitoring is a critical aspect of self-regulated learning because it provides learners with self-generated feedback regarding their own performance (Butler & Winne, 1995, Winne, 1996). Without it, efficient control over one's cognitive system may be very limited. The map appears to have helped some learners to monitor their location and aided self-reflection or self-awareness about how they approached studying as evidenced in their comments. Learners identified the map as a "visual aid", "memory aid" or "mental map" which appeared to better support visually oriented learners.

However, the extent to which many learners self-monitored using the map appeared to be sub-optimal. Based on the available eye movement data, studying the map in its entirety was rare during the study period and occurred more at the start and end pages with learners observing larger segments of the map more at the start page and during the first third of the session than the rest of the session. Learners who did not view the map at the mid-point were more likely to neither observe the map for the remainder of the session nor at the end, thereby not benefiting from a final review to compare their mental image of the content to the map. The relationship between learners' rating of the map's helpfulness and the extent to which the map was viewed was detectable only for the final page. Participants who rated the map as slightly useful or not at all useful did not view the map beyond navigating whereas participants who rated the map to be extremely useful were more likely to view most or the entire map during the last study page.

Despite the fact that most learners did not use the map as a central tool for review, the eye movement data showed that learners did observe distinct portions of the map at certain points while studying. Examining map observations in conjunction with the text suggests that the map may have indeed served as a review point, but just not at a global scale. On average participants moved between the map and text areas nine times per study page, suggesting that learners were making some sort of connection between the text and the map. To truly understand what purpose the map served would require knowledge of the intent of the learner: learners may have been creating connections between the text and map components, re-affirming these connections, or simply have been distracted at different points in time. Without information about the intent of the learner, fully understanding the map's effects at this level is not possible.

Zimmerman's (1994) supposition that a learner's monitoring varies depending on their level of expertise may explain why extensive review using the map did not occur. Novices monitor smaller "pieces" of learning, such as words. More experienced learners are able to monitor larger components such as paragraphs. Learners in this study experienced an unfamiliar learning environment. As novices in this sense but not necessarily as learners, the participants may not have been able to monitor their learning beyond the text and small chunks of the map. Therefore, the data did not show broader use of the map and much more emphasis was placed on the text as evidenced by the learners' eye-fixations and comments. Wright, Hull and Black (1990) as cited by DeStefano and LeFevre (2007) found that participants who were allowed to refer to a diagram from any point rarely did so while reading the text and therefore it did not affect reading. It seems that although there is potential for navigational maps to be useful in learning, learners may not know when to best consult such an image while studying.

Overall Map and Text Use

I had anticipated some differences between map and text use, but not to the extent described above. In terms of group differences, I had postulated that, "*Learners who do not control the topic sequence, but can see a general pattern to the order (clockwise group), will spend less time examining the navigational map, compared to the other two groups."* The data suggested a slight difference. The yoked group made 7% fewer fixations, spent 9% less time, and made 4.5% fewer distinct observations on the map compared to the free group. Learners who received the peer-sequenced topic order difference may not have found the map useful or personally relevant and thus, spent less time working with it. Some comments from the open-ended responses support this.

However, analyses on the fixations, distinct observations of each LookZone and time on each determined that these group differences were not detectable. In spite of this, some noteworthy overall discrepancies emerged. Most responses to the open-ended questions querying learners about their learning experience revolved around the map, even for the questions on learners' general studying experience, yet it did not appear to be the focal point while studying. Even though slight differences occurred between the number of unique observations of the text and map, learners spent four times longer and fixated four times more on the text than on the map during the entire studying period. Learners appeared to know that the map was important, but overall did not know how to capitalize on its affordances or chose not to.

The learners may have perceptions that textual information was more important than diagrams since text is more commonly encountered in academia. The participants were likely unfamiliar with reading text using a concept map (Chang et al., 2002) and studying the map as material-to-be-learned. Familiarity with the text also had potential implications on working memory. Processing hypertext requires an allocation of cognitive processing to make sense of the format. Processing conventional text on the other hand requires less working memory to decipher the format (Eckhardt, Probst, & Schnotz, 2003). In light of the relative newness of the learning experience and likely increased cognitive load, learners may have compensated by adopting strategies to simplify the learning activity and therefore attended to the text to free up some of their working memory. As Neiderhauser and Shapiro (2003) asserted, strategies may influence learning and simultaneously a learner's strategies may be influenced by the content and learning task's level of conceptual difficulty.

Self-ratings of Learning

Learners generally rated their overall learning experience positively and the mean self-ratings for each condition group appeared high, ranging from 3.24 to 4.24 out of a possible 5 points. Furthermore, plotted means of self-ratings of learning across the study period revealed similar patterns for all treatment groups. I had hypothesized that learners who lacked control over topic selection and who were subjected to peer-rationalized sequences would self-rate their learning more negatively. These learners had the highest likelihood of experiencing confusion and frustration, which could have become debilitating (Hill & Hannafin, 1997). However, statistical analyses did not detect a difference. Overall, learners who had difficulties with studying tended to take longer to study, made more fixations and self-rated their learning more negatively. The relatively high and consistent averaged self-ratings of learning suggest that learners' studying experiences did not change over the study period. These self-ratings were provided throughout the study session and are likely a more accurate depiction of learning as compared to post-study ratings

Self-ratings of learning were closely related to other variables and indicative of the complex nature of learning. Students who self-rated their learning higher also perceived themselves as being more familiar with strategic knowledge demands of the learning task, their strategy use and learning effectiveness, had more prior knowledge and reported a higher level of motivation. Knowledge of one's self is closely linked to the learning experience, so the more metacognisant a learner, the increased likelihood that learning will go smoothly and be a positive experience. Prior knowledge is frequently cited as a factor in governing strategy use and learning. Learning the basics of novel foods will likely be easier for learners with some domain knowledge, thereby influencing perceptions of their learning experience (Niederhauser & Shapiro, 2003).

Meanwhile, motivation is needed for self-regulation and more effort is expended when a learner is motivated (Pintrich & DeGroot, 1990). In this study, self-reported motivation was strongly correlated with both perceived knowledge and regulation of cognition and had a moderate relationship with the map utility rating and recall score. Motivation has been cited to account for a tenth of the variance in general and short-term learning achievement (Schiefele, et al. as cited by Ainley & Hidi, 2002).

The Map's Usefulness for Learning

The map utility scores for each group suggested trends for the treatment groups. Having control over topic selection or using an instructor-selected sequence was related to higher ratings of the map's usefulness, while following a peer-selected sequence was associated with slightly lower ratings. However, the differences were not statistically detectable. Overall, the map utility rating was moderate and learners' rationales for their ratings reflected an overall positive attitude toward the map with similar comments to Puntambekar, Stylianou, & Hübscher's (2003) finding where their participants reported their map as being useful for locating information related to their goals and identifying relationships, particularly for the active concept. The relationship between the map utility rating and fixation activity on the map during the first and last study pages was only detectable for the latter. Since the map utility rating occurred after the study period, the score may have been reflective of how useful learners found the map to be at the end of the session.

Eye movement Data Insights

The eye movement data also provided some insight into general studying behaviours in an online environment; this level of detail has not been reported elsewhere to my knowledge. First, it was intriguing to learn that in this study, learners were not fixated for 19% of the time. This raises a question for future research on what happens during almost one-fifth of one's studying time. Second, Rayner, at al. (2005) reported that average reading fixation durations are 200-250 *ms,* falling within the broader range of 50 to 500 ms in general eye movement research. The average of .32 seconds (320 *ms*) in this study occurs within the broader range. However, by Rayner et al.'s standards this may be a little slow, suggesting possible difficulties with comprehension or differences between the study's participants and those in previous research studies. One last item of interest resulted from observations that only eye movement data could provide: The average number of fixations by learners was 1,525 for a 10-minute study session, indicating that a lot of eye movement and cognitive activity occurs when moving through study material.

Effects on Achievement

Earlier, two hypotheses were proposed:

H_1: Learners who control the topic sequence (*free*) will perform better on the achievement measures compared to learners who were directed in an instructionally rationalized sequence (*clockwise*) or learners guided by a peer's selection (*yoked*).

H_2: Learners who are guided through the content in an instructionally rationalized order (*clockwise*) will score higher than the other two groups.

Assuming that the recall and application scores were products of the studying experience and indicative of learning, map effects and individual influences may provide insight into learning. In terms of associations with individual characteristics, the recall measure had strong positive relationships with GPA, prior knowledge, self-reported motivation and interest and map utility rating. The recall measure had a moderate negative relationship with one's comfort with learning online. However, GPA, self-reported interest and the map's utility rating were the only detectable relationships with the application score. This illustrates the interrelations among factors influencing learning and achievement.

Based on Bloom's taxonomy, the ability to apply new knowledge is contingent upon having lower order knowledge and acquired over time (Bloom, 1984). Therefore, it was expected that differences in achievement would occur in the recall measure if at all because the learners generally had little prior knowledge and only 10 minutes to study. Noticeable differences between the mean scores suggested that having learner control resulted in better achievement on the recall measure, whereas there was little variance on the application measure between the treatment groups.

Putting comparisons between the free and yoked groups aside for the moment, an alternate hypothesis posited higher achievement for the clockwise group. The instructionally sequenced topics might provide a compromise between learner control and strict program control. It aimed to alleviate learners from having to decide on a topic sequence and to provide an instructor-based order. By receiving a pre-determined order and using the image, learners' cognitive processing is minimized while they interpret and connect information (Vekiri, 2002).

Despite these intentions and expectations, no detectable differences between the treatments groups were found for either achievement measure. This is consistent with many of the previous studies on graphic organizers and navigable concept maps (c.f. Chang, Sung, & Chiou, 2002; Halpin, 2005; Lunts, 2002, Maier, 2002, Shrader, 1999). Before moving on to why learner control did not result in detectable differences in achievement and the implications of this study, one question remains: what did influence the achievement scores? The exploratory regression analyses for both test questions showed that GPA, prior knowledge and reported level of interest contributed to the prediction models.

GPA has been attributed to be a relatively reliable predictor of success in academia, so its presence further strengthens this notion. Prior knowledge is another factor related to achievement and was the most commonly mentioned point by the learners across all questions. Learners appeared to be very much aware of their level of prior knowledge, how it affected their learning and the extent to which the content fit. In the regression models, prior knowledge contributed to the prediction of the recall measure, but not the application measure. Though maps boosted learning from text, Schwartz, Ellsworth, Graham and Knight (1998) found that students benefited more when the map contained familiar content (cited in Vekiri, 2002). Recall assessments tend to rely on facts and information explicitly found in the material that was studied, hence learners with some prior knowledge would likely score higher on recall measures. The application score, on the other hand, relies on demonstrating implicit knowledge. Even with prior knowledge, the learners in this study may not have had an advantage over the low prior knowledge learners in applying what they knew. Ten minutes of study time may not have been sufficient.

The participants in this study remarked on their level of interest in the topic and interest that resulted from interacting with the map. Combined, these two types aid cognitive functioning and learning. Learners with well-developed individual interest may be better able to cope with pertinent but boring content, while situational interest derived from the text may help learners to maintain motivation and performance when a learner lacks topic interest (Hidi, 2001). This was evident through some of the learners' remarks. Moderately correlated with both achievement measures, map utility and prior knowledge, interest appeared in the regression analyses for both achievement measures. Kalyuga, et al. (2003) also noted that fostering interest through personal relevance depends on the learner's level of experience. The results from the recall model in this study support this idea since prior knowledge also entered the model.

Concept Maps in Responses

Forty percent of the participants drew portions of a concept map in response to the recall question, suggesting that these learners at the very least paid some attention to the content rather than merely using it as a navigational tool and perhaps they employed the map differently than other learners. Although diverse in their level of detail, these learners may have engaged in deeper processing by constructing a mental representation and integrating new information with their prior knowledge, akin to what Puntambekar and Goldstein (2007) found when students were given a concept-mapping test. To examine whether there were differences, a newly created dichotomous variable entered into a multivariate analysis with the achievement scores and map utility score. The analysis revealed a detectable effect. Upon closer examination, the effect was not for either achievement measures, but rather map utility ratings. Learners who drew in their response rated the map's usefulness higher.

The lack of detectable differences in the recall score between learners who created a map and those who did not may be explained by the manner in which points were assigned for the question. The learners acquired marks for every identified concept, idea from the text and connection between concepts in their written responses. Marks did not vary according to whether the answer segment was derived from the text (specifics about a topic) or the diagram (high-level concepts and their relationships).

Indirect Influences of Individual Differences

Results suggest that map effects are not easily determined and may be mitigated by individual differences such as prior knowledge, GPA, perceived knowledge and regulation of cognition, and reported motivation and interest. In addition to direct influences on learning, individual characteristics may also have an indirect effect through their associations with one another.

Reported interest and motivation did not differ statistically between the treatment groups. However, in three regression analyses, interest or motivation appeared to be predictors. Learners' self-ratings of learning relied partly on their reported level of motivation, which in turn could have been internal or externally construed. Interest was moderately correlated with motivation, indicating that they are separate, but related constructs. Interest is a specific motivational construct (Alexander & Jetton, 2003) that has been linked with deeper processing, effort, enjoyment, attention and learning (Wade, 2001). In this study, interest was a significant predictor of the achievement scores, whereas motivation was not. This suggests that learners' scores were more likely a result of internal factors, which may be indirectly influenced by the content and a learner's interaction with his environment, but reflective of personal meaning and developed over time (Hidi, 2001). Learners' comments confirmed the importance of interest. The promise of an extra monetary reward for the highest scorer, an extrinsic motivator, did not seem to be a factor since motivation did not appear in the model. While more statements reflected interest, some learners reported disinterest in the topic, noting difficulties with maintaining motivation. For these learners and for those who merely indicated that they were disinterested, their approach to learning and self-regulation were likely affected.

Now to add another layer to the mix of individual characteristics that may influence performance. In this study, both self-reported knowledge and regulation of cognition had a moderate to strong relationship with self-rated motivation. Neither metacognitive subscale had a detectable relationship with self-reported interest, but did have a strong relationship with each other, which was consistent with Schraw and Dennison's (1994) finding. Schraw and Dennison (1994) investigated the link between knowledge and regulation of cognition through self-reports of metacognitive awareness. They found that knowledge of cognition was related to achievement, while regulation of cognition was not. Hartley and Bendixen (2003) also used the MAI in their study on the relationship between the use of comprehension aides and metacognitive knowledge. They found only one relationship for these two measures: a relationship between the number of non-linear moves and regulation of cognition.

In the present study, the knowledge of cognition score was a predictor of self-ratings of learning, suggesting that perceived knowledge of cognition is closely related to achievement, but not directly to achievement as measured by the test questions. Neither perceived knowledge of cognition nor regulation of cognition was a significant predictor for achievement. Since the scores are self-reported, rather than actual measures of metacognitive awareness, this suggests that the perceived level of awareness does not adequately represent actual metacognitive awareness, which is thought to positively affect achievement.

In sum, the relationships between GPA and prior knowledge and achievement have been examined closely in previous research and are supported by the current study. In this study aside from the influences of GPA and prior knowledge, perceived knowledge of cognition and self-reported motivation contributed to self-ratings of learning, while interest was a factor in the prediction models for both achievement measures. Further research is needed to better understand the subtle relationships and effects of these internal constructs.

Contributions and Implications

The general purpose of the present study was to investigate learning with a navigable map. Building on previous research on overviews and learner control, the study examined whether control over the topic sequence affected self-ratings of learning, recall and application. The learner-control or free group had the freedom to study topics of their choosing, while the peer-sequenced or yoked group followed the topic sequence established by a peer who had learner control. Detectably better performance by the free group as compared to the yoked group would suggest that learner control over topic selection and its sequence are preferable, whereas better achievement scores by the clockwise group would support the notion that a system-controlled topic sequence is desirable, with the sequence instructionally rationalized by someone knowledgeable about the subject matter. None of the key data, the self-ratings of learning, the scores on the achievement measure or the eye movement data demonstrated detectable differences between the learners who controlled their topic sequence and those who navigated through a predefined sequence. Although no detectable differences were found, some important considerations and implications emerged from an analysis of the data. The navigable concept map and data on eye movements while studying are unique and important contributions to the field. They are not discussed individually in the next section as their value has been described in previous chapters, but rather they are contextualized within the sections below.

Implications of "No Significant Differences"

Likely, the simplest implication of this study is the conclusion that control over topic sequence is not necessary for better learning. Most studies on graphic organizers, navigational aids and learner control have identified no significant differences with varying levels of learner control. For example, Chang, Sung and Chiou (2002) proposed a hierarchical hyper concept map course system. They did not find detectable differences in achievement between the concept map and navigation map designs. Burke, Etnier and Sullivan (1998) examined navigational aids and learner control and found no detectable differences in test scores and time studying, but indicated that learners preferred learner control with a navigational aid. Shrader (1999) concluded that learner-control sequencing or advance organizers did not influence students' test scores. Burke (1998) examined the effects of a structural overview and learner control. Again, no differences were found on achievement even though learner-control participants chose to view more screens than the program-controlled group and therefore spent significantly more time studying. The list goes on.

Some studies on the other hand, have found detectable differences such as Puntambekar and Goldstein (2007) who examined how providing a visual depiction of the content's structure affects navigation and learning, and whether students learn from the representation regardless of its structure if they use it continuously. Students who received the map performed better on the concept-mapping test demonstrating a deeper and richer understanding of the content and its connections. This however, was not the same as a recall measure, which is the most common performance measure across studies.

Finding no differences in the achievement measures between the treatment groups may suggest that the graphical nature of the navigable concept map alone was sufficient for learning. The reported effects of hierarchical navigable maps in previous research studies may have resulted from the use of an image, which took advantage of the learners' visual working memory rather than improved performance being a product of learner control effects. The lack of differences across the treatment groups may also suggest that the level of control in this study was too minimal to have any effect. Although Rouet and Passerault (1999) recommended small grain data for questions about the cognitive consequences of a particular interface feature, in this study and perhaps others, learner control over topic sequence may have been too fine-grained. This is related to how a researcher defines learner control and implements it. In the present study, learner control refers to the extent to which learners are able to determine the topic order of their instructional content and instructional pace. From Maier's (2002) perspective, this would not be a "high" degree of control since, for example, the map tool used in this study did not enable learners to skip or revisit topics, nor decide on the amount of feedback they received during the study period.

The mixed results in the literature are partly the result of having neither a standard classification system nor standard definitions (Vekiri, 2002) of map use and learner control. Future designs need to re-examine and possibly redefine the question around learner control. For example, perhaps learner control over initial topic selection really has no effect and is too fine grained to matter rather it may be more important to ensure that learners access all key topics while studying and that the supports that are in place to aid this requirement. A study by de Jong and van der Hulst (2002) validates the notion that sequencing does not matter. Learners who received a visual layout of the hypertext's structure engaged in an exploration pattern that was more domain-related when compared to the control group. Although better recall was not found, learners were significantly better at demonstrating knowledge of the structure than the control group or a group that received highlighted hints. The researchers suggest that the image communicated knowledge in its own right, which was not dependent upon the route learners took through the content.

On the other hand, one of Goldman's (1996) explanations for mixed results in research investigating learning in hypermedia considers the match between task demands and what can be done in the online environment. Compared to an outline and text-only group, learners studying with graphic organizers learned more hierarchical relations and were more successful in applying new knowledge (Robinson & Kiewra, 1995). However, if the instructional goal is for learners to learn facts then the use of a graphic organizer is not appropriate because they are best at organizing concepts rather than serving as stores for recall (Robinson, 1998). In the present study, learners were asked to document everything they could remember including the key concepts and their relationships; however when scoring occurred, the concept and relationships were counted as idea units. If learners included a diagram in their responses, its components were scored as idea units. These idea units, which represented key concepts and relationships learners derived from the map, were not differentiated from the recalled information from the text, so potential map effects may not have been identifiable.

The possible mismatch between the task, online environment capabilities and performance measures is further supported by the apparent lack of influences by knowledge of cognition or regulation of cognition measures. Whereas Dennison and Schraw (1994) reported that students' knowledge of cognition positively influences achievement, knowledge of cognition did not appear as a significant predictor in the regression analyses for the two achievement measures in the present study. It was however, a significant factor for self-ratings of learning. These findings may suggest that the self-reported knowledge of cognition measure was actually a good predictor of achievement; participants' self-ratings supported this, but the learning acquired did not match what was being tested by the achievement measures.

Furthermore, Goldman (1996) suggested that branching options within a hierarchical map might not serve any functional value if the learner's task is to recall information. Effective use of hypermedia capitalizes on its links and connections and induces learners' self-monitoring, self-evaluation and decision-making at a greater level than needed by recall tasks. Nilsson and Mayer (2002) proposed that navigating using a map might make the task too easy and information integration optional. They therefore suggested that the learners and their goals should drive hypertext design. Similarly, Robinson and Kiewra (1995) acknowledged that although graphic displays present relationships between concepts, their efficient structure might result in superficial processing and therefore weaker learning. These counterproductive effects may not be readily apparent and depend on the achievement measure. Shapiro (1998) examined structured and unstructured systems and found no differences in a short-answer pre-test, but reported detectable effects on essays where learners in the unstructured condition wrote the highest quality essays. She suggested that more structured systems mitigate the need to deeply process information in the links.

Scores on the recall question in this study were generally higher than scores on the application question, but overall they were low compared to the possible 68 points for the recall measure. Based on Kintch's (1988) Construction Integration Model, it remains unclear whether the map provided effective textbase and situation representations. Scores on the questions may have been affected by the constraints imposed on learners in this study (discussed in the limitations section). The lower scores for the achievement measures may indicate difficulties with extracting and applying information to answer and provide advice to a given scenario. The extent to which learners in this study engaged in planning their studying is questionable as noted in the findings. Reasons may include challenges with the instructions, perceptions that planning was not necessary for a 10-minute session, lack of awareness of planning strategies, or a mismatch between the plan and studying activity (e.g. the unfamiliar environment and time constraints).

A lack of effects on the achievement measures may not mean there are no effects. Even though many studies have reported no statistically detectable differences in achievement measures, some have described other effects. Maier's (2002) study examined the impact of learner control over sequencing in web-based instruction. The study did not find any detectable differences in the retention and transfer scores of the two groups, but did find relationships between learner characteristics, the amount of time they were engaged in studying, sequence strategy, retention and transfer. Even if overall achievement is not directly affected, graphic organizers may have indirect effects on learning by instilling a stronger sense of the information structure in learners (c.f. de Jong & van der Hulst, 2002). Further investigation may be needed to establish direct and indirect map effects.

This section proposed some implications stemming from the lack of detectable differences between the treatment groups. Other researchers explain the lack of treatment effects in terms of a disparity between the instructional design and instructional goals and the related achievement measures. Another consideration however, is the match between design, the learner and her needs.

Designing with the Learner's Background in Mind

Deimann and Keller (2006) noted that inherent problems with learning in multimedia environments exist, but have found limited explanations in the literature, and pointed to an additional problem of inconsistent results. As described in this paper's literature review, learner control research has been inconclusive, but a reoccurring theme appears to be an emphasis on designing for the learner. Learner control appears to be highly dependent on learners' abilities.

Most of the learners in this study had low to no prior knowledge of the subject matter, and the few mid to high prior knowledge learners were scattered across the groups. Structured program-controlled environments tend to benefit low prior knowledge readers while systems with more learner control empower high prior knowledge learners (Niederhauser & Shapiro, 2003). In this study, prior knowledge was not a factor in assigning participants to groups so the proposed advantages of topic sequencing may not have been exploited. Several researchers have noted that students may not have benefited from their treatments because of prior knowledge differences. Chang et al. (2002) for example, reasoned that the students with high prior knowledge likely had their own framework and did not require the organization and structure that their concept map presented. Additionally, Puntambekar and Goldstein (2007) observed that high prior knowledge learners missed important information because they ignored the map and its portrayal of the most important concepts. It appears that some additional support may be needed for high prior knowledge learners to make the best use of a navigable concept map.

Despite the fact that some learners commented on the simplistic nature of the map, caution is needed to ensure that too much information is not provided and that the information provided is clear; recall that some learners in this study also remarked that there was too much information provided on the map. Colour coding related nodes may help learners with low prior knowledge to develop situation models (DeStefano & LeFevre, 2007) and a few learners in this study proposed that approach. This suggests that designs for specific groups of learners may be warranted or at minimum, that selected research participants are representative of a certain learner group that are hypothesized to benefit from a particular feature. For instance, Maier (2002) investigated sequence control in web-based instruction involving students with a high subject ability level, proficiency in hypertext navigation and interest in the topic. Students received a linear or linear plus non-linear navigation option. Relationships between learner characteristics, time on task, sequence strategy, retention and transfer were found.

I had selected the hierarchical structure of the map because of its reported benefits in aiding learners with reconstructing the content's structure in both print and online environments (e.g. Niederhauser & Shapiro, 2003). The hierarchical format was surmised to help learners with less domain knowledge to integrate new information into their mental representation of the given topic (Potelle & Rouet, 2003). Based on comments from all learners, the hierarchical format was generally valued. Comments about the map's format were similar across learners with varying levels of prior knowledge.

Prior knowledge however, is not sufficient for learning online. Research on learner control suggests that learners with high prior knowledge and self-regulatory strategies benefit from learner control that allows for more conscious decision-making (Chung & Reigeluth, 1992; Scheiter & Gerjets, 2007). The control over topic sequence, for example, may sustain motivation and interest. Additionally, prior knowledge and learners' metacognitive skill significantly predicted recall when a map was complex (Schwartz et al., 2004). It appears that learners' self-regulatory skills are also another important factor to consider in navigable concept map research.

Dealing with "Disorientation"

My use of "disorientation" in this section extends the definition provided in the literature review to capture the scope of a learner's disconnect between his learning environment and the task at hand when there is a mismatch between his abilities and the instructional design. This includes negative effects on working memory. Disorientation attributed to online environments may occur as structural disorientation, whereby learners are unable to identify their location within the hypertext, or conceptual disorientation where learners do not have the ability to connect the different concepts in the hypertext, resulting in fragmented rather than coherent knowledge (Cress & Knabel, 2003). The navigable concept map in this study was what Cress and Knabel defined as a global tool, which helps to reduce disorientation by aiding the students with the hypertext as a whole. Global tools are applicable to closed hypertexts with a defined text base. To address the commonly cited "lost in hyperspace" problem, the navigable concept map served as both a navigational tool and a representation of the content's structure. Attempting to reduce one type of disorientation however, may have resulted in increased disorientation in another form.

Disorientation may result from the learner's attempt to balance their focus on the instructional material and navigation. If they attend to the material, they spend less cognitive resources on navigating and this could result in the feeling of disorientation in terms of one's location within the content. On the other hand, if the learner attends to navigation a great deal then less cognitive resources are devoted to information processing, thereby reducing the amount of learning and comprehension (Graff, 2003). A map similar to those for physical environments may help navigation, but is not a prerequisite for effective learning (McDonald & Stevenson, 1999). Learners' perceptions about the text structure affects navigation and furthermore, how learners work through the text and which topics they select influences learning from hypertext. Therefore, the extent to which a navigable concept map represents the structure affects learning.

Dee-Lucas (1996) observed that learners could use the structural information to create a representation of the text. Links need to be used for more than just navigation and to indicate conceptual relations in order to encourage the learner engagement needed for deep learning beyond the acquisition of mere facts (Shapiro, 1998). Learners' abilities to navigate, engage with the content and create a representation of the text rely on a few assumptions: that learners are metacognitive and are able to self-regulate their learning, that learners have some prior background or foundation to support the learning task, and that learners know where to go and what to do with the learning tools provided to them. We will explore each of these assumptions next.

Learners are Metacognitive and Self-regulate

Research indicates that metacognitively aware learners are more strategic and perform better than unaware learners (Schraw & Dennison, 1994). Self-regulated learning is particularly important for online environments where learners need to make decisions about what to study and how to learn, time management, accessing other instructional materials, and adjusting plans, strategies and effort (Winne, 2001). The online environment adds a further challenge where learners must split limited cognitive resources between reading and making decisions about navigation. Proponents of learner-controlled environments assume that learners are skilled at metacognitive monitoring and metacognitive control (Jonassen, 1986), but this may not necessarily be the case and other factors are likely involved. Goldman's (1996) remark about learners and hypertext in general applies to the present study: learners may not have been skilled enough to monitor and regulate their studying in this particular non-linear environment.

The design and implementation of the navigable concept map intended to support SRL by providing structured materials and the opportunity to self-regulate (Zimmerman, 2001). Learners had moderate to high scores on perceived metacognitive awareness. There was evidence that some learners attempted to draw connections between the terms given the images created in their recall responses. The extent to which they self-regulated their learning, especially using the map to monitor, however is dubious given the eye movement data. Narciss et al. (2007) remarked that research has revealed that many learners fail to control and regulate learning online because of deficits in skills to deal with the additional demands posed by the learning environment.

The lack of significant results in this study could have resulted from members in the free group lacking the ability to make appropriate topic selections and capitalize on the affordances of learner control. This would be in line with Rieber (1991) as cited by Vekiri (2002) who found that learners often do not know what information they need to study from a display and are likely to make erroneous conclusions from their observations. The learners in the free learner control group lacked direction. Low prior knowledge learners may have struggled with determining where to start and with following an appropriate pathway as evidenced by a few responses to the open-ended questions. One of the problems with using hypermedia environments for teaching and learning is that learners frequently report having difficulties remembering the location where information can be found and in keeping track of the steps within a learning sequence that will lead them to meeting instructional goals (Schwartz et al., 2004).

Overall, the learners in this study may have been poorly equipped to make effective decisions on what to learn or how they could best learn using the tools provided.

Eckhardt et al. (2003) suggested that the efficacy of learning aids in online environments is mediated by learners' metacognitive skills. Hypermedia environments make greater cognitive demands compared to conventional text because hypermedia environments require more cognitive resources to make sense of the unconventional structure.

Learners have Some Background

Participants in this study generally had little prior knowledge of the topic and attributed their difficulties to this; many stated or implied that they thought having prior knowledge of the topic would have been beneficial. Learners without some prior knowledge may become lost in the environment, and have difficulties with understanding the content and determining both what information they need and where to find it. To benefit from the many cross-connections offered by hypertext, learners need a knowledge base to build on (Goldman, 1996). Lacking prior knowledge may make learning especially difficult for learners with limited metacognitive skills (Lawless & Brown, 1997). This may be explained by DeStefano and LeFevre's (2007) finding where learning was impaired due to increased demands on learner's cognitive processing when decision-making and visual processing were required. In Vekiri's (2002) review, she noted that the design of instructional materials might compensate for low prior knowledge learners' lack of strategies by breaking down information and using prompts such as descriptors and labels to direct learners to important content. To model this, the map in this study aimed to help chunk information and the labels were representative of key terms.

The interaction between prior knowledge and text structure have mixed results in research, but generally it seems that hypertext may be more challenging for low prior knowledge learners (Mobrand & Spyridakis, 2007). Research on hierarchical structures in traditional text suggests the superiority of highly organized structures; however, hierarchical structure is not required to benefit low knowledge learners. Rather the benefit is gained from the conceptual relationship that is demonstrated (Niederhauser & Shapiro, 2003). Learners' comments to the open-ended questions in the present study indicated that the conceptual relationship was recognized and deemed beneficial. Some learners described connecting new knowledge with existing frameworks in a personally meaningful way, suggesting not only some prior knowledge, but also an ability to self-regulate.

Having some prior knowledge does not however ensure further learning either. A few comments by the participants in this study questioned the layout and terminology used in the concept map, suggesting some level of prior knowledge and a discrepancy between it and the presented content. When the content's structure does not match previously stored information for learners who have prior knowledge, there is a conflict and each representation competes for cognitive resources (Mobrand & Spyridakis, 2007). When the text structure does match an existing framework, then interpretation and recall are easier. Puntambekar and Goldstein (2007) also found that high prior knowledge learners missed important information because they ignored the map and its portrayal of the most important concepts. It seems that prior knowledge can counteract self-regulation as exemplified in the present study when a learner reported challenges with pacing because of his prior knowledge.

Learners Know Where to Go and What to Do

Mixed results in research may be a result of the interface design and learners' unfamiliarity with the system and its functions (Chang et al., 2002; Goldman, 1996). The map's role as an advance organizer was posited to assist learners with navigating and locating information in electronic texts, as found in other research such as Dee-Lucas and Larkin (1995). However, in the present study, few learners examined the map prior to studying and as a result likely did not get a sense of the overall structure. The navigable concept map aimed to present a mental model that integrated the text with the content's structure, which the learner could then use in order to deeply comprehend the structure and meaning of the content and to make thoughtful topic selections. Cognitive load would be high, but germane. For some learners the potential of the graphical map was not realized, possibly because it was extraneous cognitive load. Rather than reducing cognitive load by providing an explicit navigational structure of the content and thus aiding learners to orient themselves, the presentation of a new environment may have instead increased cognitive load. This placed demands on learners' limited working memory that detracted from the process of learning the content, thereby reducing the value of metacognitive skills. This may have been even more challenging for the free group since learner control is related to cognitive load and learning (Morrison, 2004: van Merriënboer, Schuurman, de Croock and Paas, 2002)

Some students' responses to questions about their studying experience and map use indicated that they found the map helpful to see the connections between the concepts, the chunking of related concepts, and the overall structure of the material to be learned. The learners generally had a positive attitude toward these features, supporting findings in previous research on hierarchical overviews (c.f. Dee-Lucas & Larkin, 1995). Providing a visual signal of one's current location within material-to-be-learned appeared to help some learners in this study. A few learners stated that they appreciated knowing their navigational path. All learners used the visual signal in order to orient the active topic within the content. However, it is not clear whether attention to the signal supported learning the concept and its connections with other topics or whether learners merely needed to know their present location before moving to the next topic.

In General

Learners who are self-regulated, have some background, and know where they are going and what to do when they get there, may be more prepared for studying in an online environment than learners who are weaker in one of these areas. Some of the specific challenges learners faced were discussed in the previous sections. High levels of disorientation have been associated with dissatisfaction and increased frustration with the learning task, but could also be debilitating (Hill & Hannafin, 1997). Significant disorientation may deter a learner from referring to relevant prior knowledge and metacognitive knowledge. Disorientation also negatively affects one's perceived ability to succeed, resulting in lower confidence and task persistence (Hill & Hannifin).

Disoriented learners may adapt by reverting to familiar strategies, such as reading the text as they do in a traditional format (Goldman, 1996). Research has indicated that people attend to text more than to graphical displays and have better skills and more experience with text than graphical information (Langan-Fox et al., 2006; O'Donnell et al., 2002). Therefore it can be easier to apply these skills rather than to building new ones. Eye movement data showed that the learners in this study spent less time and performed fewer fixations on the map compared to the text. A few learners in the yoked group appeared to deal with the task demands and challenges of the learning environment by ignoring the map, devoting energies into learning the textual content and thereby negating learner control and map effects. In their case, the treatment effects might have been more negative. Without spending sufficient time on the map, learners will be hard-pressed to benefit from its potential.

As Paris (2003) surmised, metacognition is theorized to depend on specific factors and learning scenarios. Self-regulation varies among learners and strategy selection may not have been appropriate for the task, or learners may have had insufficient time to familiarize themselves and to adapt learning strategies to this particular environment. Even assuming learners are metacognitive, most people appear to have difficulties with determining how to navigate through large quantities of content to optimize learning (Eveland et al., 2004)

Provide Support

Through the present study and reading related research it is evident that other factors aside from the independent variables of the study affect the student's learning experience and may contribute to the mixed results. There appear to be two factors that we as designers and instructors can mediate by providing support to learners. The first factor is support to improve self-regulation and the second, training or an orientation. Monitoring is often far from optimal even by metacognitively skilled learners (Pressley & Ghatala, 1990) and likely more challenging with a new online environment; the farther removed content presentation is from conventional text structures, the more metacognitive skills are needed to make sense of the structure and content.

One of the two categories of computer-based instructional interventions Hadwin, Winne and Nesbit (2005) described would be ideal to provide this support: an environment that not only reduces learner's work and related cognitive load so that more cognitive resources can directed to learning, but also provides learners guidance and tutoring to scaffold their learning. The required resources for developing such a system are likely beyond what is available to instructors and content developers. In actuality, the support need not be complex, as having some support is likely better than having none. For example, Kauffman (2004) implemented self-efficiency building feedback and self-monitoring prompts and found moderate effects on achievement. Williams (1996) suggested that directing learners to think about their level of knowledge might alleviate the more familiar "mindless" activity. Asking learners in this study to indicate how well their learning was going for each topic had the potential to increase self-monitoring, which could have affected their approach to learning and their performance. However, given the relatively low test scores and few learner comments related to this activity, all of which were negative, positive effects resulting from the prompt were unlikely.

Additional support in the form of directly informing learners of their progress, prompting to gauge their current knowledge, or training may assist low prior knowledge learners with their self-monitoring. Learners with more prior knowledge appear to be more metacognitively aware and able to assess their learning, determine what they require and make decisions about their learning. Therefore, providing metacognitive scaffolding in the form of coaching or advisement may encourage longer-term metacognitive processes in low prior knowledge learners (Vekiri, 2002).

Even though metacognitive skill may be necessary for learning in online environments, it is not sufficient in and of itself. The learner needs to be motivated to deploy their metacognitive skills to regulate their cognitive strategies in order to construct meaning from the online environment (Schwartz et al, 2004). When learners have trouble with a new environment, motivation and persistence with learning may decrease. Therefore, a second form of support that may be offered is an orientation or training session to familiarize learners with the environment and its features.

Disorientation as I have referred to earlier may be addressed by helping learners to develop system knowledge. Learners need to learn not only the content, but also the structure of the system (Puntambekar & Stylianou, 2005). At least some base level of prior knowledge and experience is needed even though improving system knowledge alone may not be sufficient for success. It is however, critical to topic selection, knowing how to interact and increase the possibility of making the most of system features (Hill & Hannafin, 1997). Providing training can help learners who are not aware of how to approach learning within a system with opportunities for practice and guidance about how the system's features may employed to meet their learning goals (Langan-Fox et al., 2006; O'Donnell et al., 2002). Given the multiple functions available through the navigable concept map in this study, prior training would likely have helped learners to implement it more effectively and affected the results of the study.

For example, learners who receive an orientating activity to alert them to the important parts of the lesson significantly outperformed learners who did not receive an orientation on recalling information (Tovar & Coldevin, 1992, cited in Burke, 1998). Research by Puntambeckar and Stylianou (2005) suggest support in the form of aiding learners with identifying their goals and prompting monitoring and reflection on link selection while studying. They found that this support on *metanavigation*, the metacognitive strategies necessary for navigation helped their students to better understand the domain knowledge and to make reasoned moves between text units. Students demonstrated this through better explanations of concepts and richer explanations of their connections.

When learning online, self-regulation and system knowledge are interconnected. Learners need to identify what is important to them and decide on what to learn next, and this requires self-regulation in navigation and learning. Learners need to understand the information space and structure as well as the relations between concepts in order to make navigational decisions (Narciss et al., 2007). Otherwise, learners will follow frames of information similar to the way they process standard text (Verrek & Lkoundi, 1990, cited in Eckhardt et al., 2003) which reduces learning potential of hypermedia systems. When using a navigable concept map, learners may require additional support to connect the information fragments and to monitor their understanding before moving onto another node. Puntambekar and Stylianou's (2005) study exemplies this where they found that students visited many concepts on a specific topic, but were unable to explain the single topics.

Despite efforts to provide clear instructions in the present study, a few students had difficulties establishing an initial representation of the task. Learners might have benefited from clearer task instructions and explicit directions and practice in using the map as an advance organizer and monitoring tool. This additional support might enable learners to establish the connections between the study and achievement tasks and to develop an initial framework for studying. The radial map in the present study could have encouraged learners to use their metacognitive skills, but without any support or guidance, it was unlikely that they made the best use of it as demonstrated by the analysis of the eye movement data.

Training and practice that explicitly covers the function of a navigable concept map and its organizational and navigational advantages may inform learners on how to best use the map so that they can determine an appropriate approach to achieve their learning goals. Unobtrusive guidance may be another means to support learners as they develop their skills in the new study environment. Providing hints on where to explore was found by de Jong and van der Hulst (2002) to result in domain-appropriate exploration patterns and to provide a better grasp of the knowledge structure by learners.

In Meyer and Poon (2001), participants trained in structure strategy learned to determine and employ basic top-level structures to arrange their ideas, whereas participants trained in interest-list strategy learned to systematically appraise their interest and monitor their motivation based on this information. They found that training for both groups resulted in positive changes. However, increased total recall occurred only for the structure strategy group. The researchers explained that the training helped increase the amount of information remembered and recalled by learners.

Finally, scaffolded support is highly recommended to provide learners with initial guidance but not to offer excessive or long-term supports, which may discourage learners from actively engaging in their learning and strategy use (Goldman, 1996).

Although providing support takes time and effort, the long-term benefits may be worthwhile. Learners would be better able to gain from online learning and researchers may obtain clearer results that are less influenced by factors extraneous to their research. This may potentially shed light on the mixed results in learner control and navigable concept map research. Now, even if issues related to individual differences, learner control, disorientation, and support are addressed, one more consideration is important.

Content Representation

"Learning difficulties may sometimes result from the design of instruction and not from the nature of the material to be learned" (Vekiri, 2002, p. 276). The design of the map may not have integrated the text with the structure, thereby preventing learners from achieving a goal to learn the structure and meaning of the content. As Puntambekar et al. (2003a) noted, an effective map does not only serve as a navigation tool, but depicts the conceptual nature of the subject matter. Hence, the map needs to be developed to best represent the topic's structure. Consultation with an expert and user testing with learners would likely produce a more accurate representation that makes sense to learners.

Several learners in the present study questioned the terms used in the concept map's links. Confusion about the links may have been problematic especially since the links were devised to be semantically and organizationally explicit. As described by Mobrand and Spyridakis (2007), semantically explicit links indicate the content of the target node while semantically and organizationally explicit links show both the content of the target node and the location of the node in the overall text structure. The researchers found that a combination of semantically and organizationally explicit links led to learner reports of following more embedded links which in turn resulted in improved performance.

Some participants voiced discontent over the unconventional means for navigation within the study. Mobrand and Spyridakis (2007) noted that some researchers believe that conventional features benefit users the most regardless of whether they are the most effective element. They argued that replacing the common "next" and "previous" links with more explicit wording would result in higher comprehension. Instead, they found that this change violated a familiar convention and any benefits that could have occurred from the explicit links were countered by unfamiliar wording. Similar effects may have occurred in the present study where the potential benefits from the navigable concept map with learner control over topics were offset by the novelty of the map, its links and functions.

Wei et al. (2005) examined generic, intriguing and informative hyperlink wording in a navigation menu and embedded links. Inferential learning and overall comprehension benefited from informatively worded hyperlinks embedded in the text and accompanied by a generically worded navigation menu. The generically worded navigation menu appears to provide a familiar standard that enables learners to handle unfamiliar informative or intriguing wordings. To counteract negative link effects in future research, adding a generically worded navigation menu separate from the navigable concept map might provide a familiar convention for learners.

The interaction between task complexity and the display format may have also been a factor in this study. Holley and Dansereau (1984) as reported by Langan-Fox et al. (2000) deduced that graphic organizers might be unwarranted for text that is less than 2,500 words. The text in this study contained 879 words. Hartley and Bendixen (2003) reported mixed results found between metacognitive awareness and use of hypermedia tutorials and concluded that their task may not have encouraged the kind of deeper processing that is more commonly associated with increased metacognitive awareness. A more authentic and longer task may have produced different results in both this study and theirs.

Summary

Although this study has contributed insights into how learners use a navigable concept map and discusses possible explanations within a metacognitive framework, the question of whether knowing one's location within a graphical map or having control over the selection and sequencing of the topics benefits learning likely remains unanswered. No detectable differences were found between the free, clockwise and yoked groups, suggesting that learner control over the order of topics studied is not a significant factor for learning, thus supporting previous research that found no effects. Nevertheless, it is fair to say that findings are inconclusive.

This section identified some key implications from the study whereby (1) the finding of no detectable differences may have multiple meanings, (2) learner controlled environments need to match the backgrounds of the learner, and (3) providing learning aids to address disorientation may result in disorientation in another form. This depends on the learner's self-regulatory skill, prior knowledge and knowledge about where to go and what to do in the environment. Possible solutions to challenges found in this research and others include providing learner support or training, and revising content presentation. The main implication and challenge to future researchers and content designers is to find the right balance of support to meet the needs of their learners while at the same time enable flexibility to accommodate varying needs within content representations that do not themselves detract from the learning process.

Placed in an unfamiliar physical and virtual study environment, restricted to a 10-minute study session with no opportunity to review text, and learning both the computer environment and content presented an abundance of expectations and goals to the learners, potentially overwhelming them. Learners divide their effort between the task of learning and the task of regulating the strategies applied to learn the content. Hence, less skilled or knowledgeable learners might have found monitoring more taxing on their cognitive resources (Winne, 1995). Most learners in this study had little prior knowledge on the topic and none of them had any previous experience with this learning environment. Monitoring of their learning was not yet automated and likely competed against the effort necessary to learn the subject matter. In sum, environmental and cognitive factors most likely affected the learners and potentially affected the outcomes of this study, leading to my suggestions for modified approaches and techniques to inform further study in this area. This brings us to the next section on limitations of this study.

Limitations

Although no detectable findings were found for learner control effects, the analyses in the Results chapter provided indications of possible predictors for performance, insights into the studying process when using a navigable concept map, and themes for learners' studying experiences with the map. These findings and suggestions require consideration within the limitations of this study. Besides the aforementioned challenges of this study earlier in this chapter, some shortcomings are particularly noteworthy for future designers and researchers:

The Learning Materials

The learning materials provided to the learners could have been a factor that influenced the study. Already discussed were whether the map accurately presented the subject matter, and the use of both unfamiliar terminology within the map and a novel approach to content navigation.

Additionally, the simple structure of the hypertext may have contributed to the lack of effect in this study, similar to what occurred in Brinkerhoff et al.'s (2001) research. Lorch and Lorch (1996) found that signalling devices such as overviews were more likely to result in better recall when they were associated with more complex or poorly organized text. The overview would provide learners with a more coherent framework for the topic structure than the one that they constructed on their own. Since each topic's text was basic and only three sentences long in the present study, the addition of the concept map to the content may have been of less use than in a situation with a greater amount of text and content that is more complex.

Text length may also be a factor for the lack of results in many studies and possibly contributed to the lack of interaction with the map in this study. Robinson and Kiewra (1995) cite supporting research where graphic organizers seem unnecessary for text shorter than 2,500 words (Holley & Dansereau, 1984) as short text do not require specific learning strategies (Anderson & Armbruster, 1982). Robinson (1998) identified the use of short texts as a limitation of pervious research because it failed to simulate conditions under which graphic organizers would likely be employed. Langan-Fox et al. (2000) also noted that small effects in their studies might be due to short text.

From a different perspective, the map aided navigation through the content, but may not have positively affected achievement. Nilsson and Mayer (2002) suggested that the act of developing one's own mental image of the content results in learning. Providing a map may result in less active thought about the content and reduce the learner's active connection of information into a coherent internalized framework. Therefore, the maps may help in navigation but not aid in the long-term understanding of the content. In their study, Nilsson and Mayer proposed that navigation could become too easy, resulting in little to no integration of information while working through the content as it was perceived as being unnecessary. Similarly, Robinson and Kiewra (1995) acknowledged that one of the strengths of a graphic organizer is its effectiveness in presenting links between concepts. Conversely, this may also be a weakness and lead to shallow processing which in turn affects performance. The eye movement data appears to support this argument: learners used the map more at the beginning of the study period and less so toward the end, and responses to the recall question revealed few relationships between the key concepts that were present in the map's labeling and structure.

Time Constraints

The allotted ten minutes for studying may not have been sufficient for creating a schema for recall. This is consistent with Brinkerhoff et al.'s (2001) explanation of the lack of detectable findings on their study on overviews. They posited that the brief time participants spent on the overviews were minimal, affecting their schema development. Robinson and Kiewra (1995) remarked that when learners are given sufficient time, they learn more hierarchical and organized relations, resulting in better application of the knowledge and writing of more integrated essays than learners who studied either outlines of the content or the text alone. However, learners in this study were asked to comply with general timeframes for all tasks in this study, whereas when learners study on their own, they have more control over their environment, studying for as long as needed and taking breaks when desired. The rigidity of the experimental design may not have been conducive to learning. The time limit for studying may have suppressed achievement as suggested by Zimmerman (1998) and his assertion that time spent on studying was a predictor of academic achievement.

The amount of text to be studied within the 10-minute time limit was based on a calculation of average reading times. Still, this may have been an insufficient amount of time even for learners who paced themselves well. The limit may not have left enough time for learners to study the map. Furthermore, although the open-ended application question was designed to measure a deeper level of understanding, it is possible that it required foundational knowledge, which could not be effectively gained within the allocated time.

Time and practice are also necessary for learners to become familiar with a new learning environment and to develop their skills in working with graphical information. For example, the eye tracking data showed that the participants focused on the text much more than the map even though it took less space on the screen. Given the prevalence of text in academia and people's experience with it, they are likely to be more inclined to attend to text than to a graphical display and are further likely to be more skilled with reading text than they are when working with graphical information (Anderson, 1996; as cited in Langan-Fox et al., 2006). The present study did not allot any time for practice within the novel environment.

Experimental Design Constraints

The study's experimental design restricted or imposed certain behaviours on the participants and provided them with new experiences. The learning environment, both online and the physical space were relatively new to the participants. No one was familiar with the navigable concept map and not all learners had experienced a lab setting, nor did they have experience working within the constraints imposed by the eye-tracking equipment. Aside from reading instructions about the study task and how the online learning environment would work, learners received no opportunities for an orientation or practice. Learning about the navigable concept map while they were studying may have imposed additional cognitive load. Whether it was extrinsic or germane, the added learning of the system likely took away cognitive resources from studying the content.

The eye-tracking equipment placed physical constraints on the participants. They were unable to move their chair and were requested to sit upright. Learners were cautioned not to make sudden or wide-ranged head movements when wearing the eye-tracker equipment because it could adversely affect the equipment's calibration and data recording. Consequently, the physical constraints of the eye-tracking equipment limited a participant's head and body movement, which also made it difficult to use beyond 10 minutes. Therefore, the studying time was to some extent defined by the study's apparatus.

After settling in and proceeding with studying, learners could refer to the concept map at any point and review it as many times as they wished because it was always available. However, once the learners left the text associated with a particular topic, they could not return to it. This was done in part to focus the study on learner control of topic selection without the possible effects of review. Additionally this constraint was in place so as not to cause distress for the learners in the yoked group and set them up for failure; had review been possible by the free participant, the yoked participant would have had to follow not only their free peer's initial topic selection, but also her review sequence.

In spite of the rationale for yoking, preventing learners from reviewing a topic was a reported issue for many learners: 29 comments were made in the open-ended responses with participants either commenting on how the inability to review affected their studying or recommending that future learners be allowed to review. Learners frequently self-evaluated in their open-ended responses, suggesting that they engaged metacognitive awareness and tended to self-regulate. By restricting review while they studied, the study itself may have curtailed monitoring, debugging and adaptation, thereby affecting learning outcomes. Furthermore, when learners were ready to proceed to the next topic, they were required to stop, consider how their learning was progressing and select the appropriate descriptor. Some participants found this disruptive.

Part of the study's design constrained or resulted in different studying approaches than the learners would normally follow since they were unable to tailor their studying environment to make it personally suitable and comfortable, something learners tend to do (Winne & Hadwin, 1998). Impositions on learners' strategies and normal studying behaviours were evident in learners' comments that they could not go back and review the text, take notes or create their own map. Some learners also commented that the monitor and font size made their eyes tired. Given these complaints and concerns, they likely would have stopped studying if they controlled the process. If participants experienced discomfort, their engagement in the study may have been affected. Unfamiliarity with the environment may have affected the development and implementation of appropriate study strategies or perhaps even the inappropriate application of existing strategies, depending on the learners' metacognitive skill.

Finally, although small effects are theoretically meaningful, the study was limited in its power to detect small effect sizes. Cell sizes of 21 per group and successful acquisition of eye movement data for only 35 of the 63 participants dictate that suppositions on map use and studying behaviours determined through the eye movement data are exploratory and tentative in nature.

Data as Evidence

I collected a wide range of data for this study, but the data itself requires consideration. Not only could the eye-tracker equipment have imposed environmental constraints, but also the data itself cannot be taken as definite evidence. The eye-tracking software can have a 40-pixel margin of error. The text and navigable concept maps in the study required a design that accommodated this limitation. This constrained the number and placement of nodes and resulted in a relatively large diagram that occupied two-thirds of the screen. Given the placement of hyperlinks within the text and the single-spaced text, ambiguous focal point data could have resulted because of the 40-pixel margin of error. Differences in information processing strategies can be measured through eye movement data, but the data does not explain why information was or was not processed (Lohse, 1997). Furthermore, data compilation may also not be reflective of learner's intentions at a metacognitive or cognitive level. For example, focal points may not necessarily be indicative of cognitive processing and fixation times, which are typically considered to last between 200-500 *ms*, but can vary between individuals and across different levels of text difficulty (Rayner et al., 2006). Lastly, due to known difficulties with obtaining refractory data for wearers of hard contact lenses or glasses these learners were excluded from the study from the onset.

Other limitations on data have already been discussed: whether the test questions were adequate achievement measures for the content and how the scoring of the responses could have been done differently to differentiate learning from the map and the text. For example, Robinson and Kiewra (1995) examined the extent to which students learned the relationships identified in the maps by measuring learning of different types of text information. Likewise, Mayer (1984) as cited by Robinson and Kiewra (1995) remarked that research should focus on what is learned rather than how much is learned.

The logic behind the design and achievement measures may have been flawed. Despite the intent to emphasize and examine map effects and as a result, limiting of the amount of text to be studied, there was still a substantial amount of apparent learner attention associated with the text relative to the attention paid to the map. The text for each topic consisted of three statements, which resulted in 51 possible marks for the text alone. Meanwhile, identifying key terms and their connections with other concepts could garner only up to a mere 17 points. The marking scheme was not explained to learners. The questions posed for the achievement measures also warrant reconsideration. It is unclear whether the application measure was sufficient to get at the deeper level of understanding, but performance on the task was likely affected by other factors such as low prior knowledge and time. As well, both questions could have been too open. Generally, achieved scores were low compared to the potential scores. Learners provided fragmented responses with incomplete ideas for the most part, which led them to receive only partial marks. Learners typically did not make appropriate links between topics, suggesting that their study tactics were not focused on identifying and integrating ideas, particularly between the map and the text content.

Accounting for Individual Differences

The influences of individual differences were speculated, but not necessarily well accounted for in this study. In addition to prior knowledge and perceived metacognitive skill, self-reported motivation and interest also appear to influence learning. Two issues emerged. First, the motivation and interest scores were self-reports and the extent to which they represent actual motivation and interest is unknown. They may be prone to different interpretations by the learners, so the construct and its measurement may vary across participants. These are however, common problems when measuring levels of motivation and interest irrespective of the instrument. Second, in this study, motivation and interest ratings were acquired at the end of the studying session requiring learners to reflect and recall what they felt while studying. This post-task reflection may have been influenced by how well they thought they performed. Monitoring learners' interest and motivation levels as they progress through a learning experience would provide insight into changes in motivation at specific points in time.

The study employed the MAI to gain a sense of learners' metacognitive awareness, which is closely tied to self-regulation. However, the scores reflect learners' perceptions of their metacognitive awareness and not actual knowledge and regulation of cognition, so results do not capture the true impact of metacognitive awareness on learning. Additionally, specific behaviours related to the knowledge and regulation of cognition were difficult to identify, resulting in general observations and speculations about interactions with learner control and map use while studying. Lastly, a means to more clearly distinguish the process and products of self-regulation (plans, goals, tactics, and strategies) would provide a more comprehensive picture of navigable concept map use.

In sum, although the study provides new insight into navigable concept map use and raises further questions, challenges existing with accounting for individual differences because of self-report data. Data traces such as eye movement data are a step toward understanding the process of studying, but results remain inconclusive.

Future Research

At the start of my study, I had envisioned (1) clarifying the relationship between learner characteristics and design factors, (2) advancing the understanding of the applications of navigable concept maps and learner control effects, (3) exemplifying the importance to home in and clearly define the scope of one's research, and (4) applying an alternate cognitive lens using the concepts of self-regulation and metacognition, which can provide important insights into the studying process. What I have found through this research is that I have only scratched the surface and have more unanswered questions than I started with. The benefit is that these questions can help to identify areas for future research.

The relationship between learner characteristics and design factors is complex. The effects of prior knowledge on learning are frequently acknowledged and documented with related design suggestions by many studies. However, knowledge of cognition and regulation of cognition are critical for self-regulated learning. Yet very few researchers have examined these two constructs or the overarching process of self-regulated learning within the context of an online graphic overview or a navigable concept map. In this research, prior knowledge may have contributed to the prediction model of one of the achievement measures, but the interaction between prior knowledge and metacognitive skill was not apparent even though other studies have referred to it (c.f. Scheiter & Gerjets, 2007). A next step to extend the existing research would be a design that examines navigable concept map effects on learners with different levels of prior knowledge, as well as examining metacognitive skill perhaps through some other means that represents the constructs better. By identifying the strengths and challenges for each group, scaffolded support can be developed for future applications of a navigable concept map.

Future research may also examine the longer-term effects of using a navigable concept map and whether some findings related to graphic organizers apply to maps, hold true over time and if so, under what conditions. For example, Hall and O'Donnell (1996) had students study a passage in the form or a knowledge map or text and then tested the students on free recall two days later. The map group scored significantly higher on recall, reported concentration, and motivation. On the other hand, Robinson and Schraw (1994) contended that graphic organizers could communicate information too effectively, causing learners to avoid expending the cognitive effort required to learn the material. The shallow processing then becomes apparent in delayed performance measures (Robinson, 1998). Learner control over sequence may aid this problem by encouraging learners to examine the relationship between concepts to decide on what to study next. On the other hand, if learners employ graphic organizers effectively and learn the concepts and their relationships they may be more resistant to delayed testing, as found in Robinson and Kiewra's (1995) study which supports findings in other studies that examined the effects of adjunct aids.

Another line of research to pursue is the different types of learner control that are possible when using a navigable concept map. In the present study, the differences in learner control across the groups may have been too narrow in focus or even irrelevant. Lawless and Brown (1997) suggested providing limited learner control where learners follow a specific path of information and only have control over pace, review and the ability to proceed to the next pre-selected topic. They surmised that learners "may not possess the necessary cognitive and affective pre-requisites (i.e., knowledge, motivation, interest) to make informed or correct choices" (p. 122). I tend to agree with the general idea given the experience I had with my research. It seems that limited learner control may ensure that learners access key information while at the same time, offering some flexibility.

However, I am not convinced that a specific path should be followed as it goes against the purported advantages of a hypertext environment. The influence of individual differences did come into play in this study, thus supporting the notion that complete learner control may not be desirable, but rather than restricting sequencing, learners may benefit from some initial guidance on how to best select and navigate through online content. Restrictions to learner control may frustrate learners that are more knowledgeable if they are presented with information they already know and must work through before proceeding to content not yet mastered (Lawless & Brown, 1997) or, as in the case of some learners in this study, when the concept map does not match an already existing schema.

This leads me to another possible line of research. Future research could compare the effects of program control and scaffolded support for learners. Designs need to be driven by learners and their goals (Nilsson & Mayer, 2002) rather than by researchers and their questions. For example, Puntambekar et al. (2003) found that learners used the navigational map and demonstrated focused navigation by examining conceptually related concepts and concepts that fit their learning goal. They indicated that a challenge for designers is to develop a hypertext system so that learners are supported, but also have enough flexibility to explore. Rather than examining different types of learner control when using navigable concept maps, empowering and educating learners may be a plausible solution. As well, it is difficult to create a learning environment that is responsive to different learners' needs, so creating an environment that is suitable for most learners and determining appropriate scaffolded support depending on individual characteristics such as prior knowledge, may alleviate the need for different environments or complex systems.

The implicit limitations of the present study were the lack of authenticity of the task and the restrictions imposed on learners during the task. Several possibilities for reducing the effects of these limitations emerge: (1) Provide a training period for learners in order to familiarize themselves with the new environment. (2) Use newer eye-tracking equipment. Eye-tracking equipment has significantly improved since the model that was used for this study and is less constraining on movement, thereby allowing longer studying times beyond 10-minutes and allows the flexibility to look down to take notes or use other familiar studying behaviours. (3) Allow both a less restrictive amount of time to study and enable the ability to enact preferred studying strategies such as note taking, allowing learners to work at their own pace and provide the researcher with rich trace data that better represents learners' natural studying behaviours.

A longer period or a series of sessions would allow learners to become familiar with the content domain, possibly resulting in increased automation of monitoring, freeing up cognitive resources that could be allotted to learning the subject matter. More time spent on learning would likely increase the quantity or quality of responses on the achievement measures, thereby providing more data for the researcher to examine in relation to the map and text. For example, perhaps differences in achievement scores still do not occur, but with more data, a researcher could establish whether there were treatment effects in the responses to the questions (e.g. reflective of information structure from the map versus snippets from the text). Multiple sessions may also help learners to build their schemas and foundational understanding of the subject matter. Learner control and map effects on higher-level cognitive processes may become more visible as a result.

Although no detectable differences on achievement were found in this study, data from self-reports and eye movements helped to explore possibilities for the findings, opening the doorway for observing map use while studying and considering how maps may be used during self-regulated learning. It would be worthwhile for future research to build from this experience by employing eye movement research more frequently to observe learners with varying self-regulation abilities to gain a better idea of the studying behaviours that they engage in. This knowledge may then enable educators to develop appropriate learning designs to scaffold less self-regulated learners. While eye movement data captures the learning process to some extent, new methodological approaches are needed to more fully examine learner control effects on studying, navigable concept map use and self-regulated learning, and learning with the use of hypertext content in general. In particular, a means to capture the dynamic and recursive aspects of self-regulation and learner control effects would greatly benefit future investigation in these areas.

If one was to build from the lessons learned from this study, there are several design considerations. Some have already been identified (e.g. time, scaffolded support), but there are more. As noted throughout this dissertation, individual characteristics play a significant role in learners' behaviour and achievement. Learners with high prior knowledge connect new knowledge to existing knowledge and can deal with text being out of sequence, whereas low prior knowledge learners lack an existing structure to help them to decide on a reading sequence (DeStefano & LeFevre, 2007). Few learners had moderate or high prior knowledge in this study and those that did were spread across the three groups. Thus, their results, when combined with those of low prior knowledge learners, may not have been strong enough to result in differences.

Research with larger numbers of participants and additional groups formed based on prior knowledge and metacognitive skill may help to better identify learner control effects. Having more participants may also determine whether high prior knowledge and/or high self-regulated learners adapt to the yoked condition. Self-reported interest and motivation appear to influence learning indirectly and may warrant further exploration. Although learners self-rated their level of interest and motivation at the end of the study, further analysis may require methodology sensitive to changes in students' reactions while learning. Furthermore, to move beyond exploratory research and tentative suggestions, future studies require substantially more participants per cell, even more so if the proposed refinements above are applied because they require a factorial design. The issue related to semi-random sampling in this study presents the need for a study with random sampling to ensure that the participants are representative of the student population.

Finally, the intention of the yoked and free treatment groups was to home in on learner control effects while controlling as many of the other variables as possible. This lead to the inability for learners to review previously read text, a critical learning behaviour that likely affected achievement. As a result, future research needs to consider a better compromise for looking at learner control over topic selection and its effects and while both maintaining an acceptable level of integrity for the research and freeing the participants to enact more natural study behaviours.

In closing, while I had envisioned having answers that are more definite rather than generating even more questions, this research has made unique contributions to the area of teaching and learning. Although the analyses showed no detectable effects for my research questions, the data I collected and analyzed provides a picture of the complexity of learning and the related factors; furthermore, I have brought together research on graphic organizers, navigational aids and learner control. I applied an infrequently used lens of self-regulated learning to the study of navigable concept maps. I also stayed true in my explorations to what Leu and Reinking (1996) asserted as being important in reading research (which also applies to learning research): when studying interactive environments, processes are more important than products. To investigate these processes well, one needs to appreciate the role of prior knowledge, strategic knowledge, interest and other motivational factors.

In addition to this, my research identified possible functions for the navigable concept map, collected and analyzed feedback from learners about their studying experience and the perceived utility of the map as a learning tool. The themes and streams derived from learners' responses, combined with the eye movement and achievement data may help future designers with developing a more learner-centred navigable concept map. Furthermore, the novel use of eye movement data was an attempt to explicate cognitive processes that occurred during the process of studying. The combination of quantitative and qualitative data and analysis that this study has produced provides multiple avenues for future inquiry in the area of navigable concept maps and issues of learner control.

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APPENDICES

APPENDIX A: ADVERTISEMENT

Participate in an online learning study. Earn $25 or $100.

Already going to SFU Surrey and have some time? Help to advance the field of online learning!

Upon arrival, you will be asked to complete a questionnaire, to wear a headband with a sensor so we can track your visual movements while you study online text. After completing two test questions and short questions on your learning experience, you will be paid $25. Top three scorers on the test will be paid an additional $75 at the end of the study.

Where: Usability lab at SIAT (SFU's Surrey location)
When: Monday, October 1 to Friday, October 19 (days, evenings and weekends)
Time: By appointment
Duration: ~65 minutes

Participants must fit the following characteristics. You:

- are an SFU student
- do not wear glasses or hard contact lenses (soft contact lenses okay)
- have normal or corrected vision
- have a very good understanding of English

Interested? Contact Stephanie at schu@sfu.ca with your preferred dates and times.

Appendix B: Consent Form

Faculty of Education

Faculty of Education

street address
EDB
Simon Fraser University
8888 University Dr.
Burnaby, BC
V5A 1S6

Graphical Navigational Aids (an Online Learning Study)
Information and Consent Form for Participants

The University and those conducting this research study subscribe to the ethical conduct of research and to the protection at all times of the interests, comfort, and safety of participants. This research is being conducted under permission of the Simon Fraser Research Ethics Board. The chief concern of the Board is for the health, safety and psychological well-being of research participants.

Should you wish to obtain information about your rights as a participant in research, or about the responsibilities of researchers, or if you have any questions, concerns or complaints about the manner in which you were treated in this study, please contact the Director, Office of Research Ethics by email at hweinber@sfu.ca or phone at 778-782-6593.

Your signature on this form will signify that you have received a document which describes the procedures, whether there are possible risks, and benefits of this research study, that you have received an adequate opportunity to consider the information in the documents describing the study, and that you voluntarily agree to participate in the study.

Title: Graphical Navigational Aids (an Online Learning Study)
Investigator: Stephanie Chu
Investigator's Department: Faculty of Education

Having been asked to participate in the research study named above, I certify that I have read the procedures specified in the Study Information Document describing the study. I understand the procedures to be used in this study and the personal risks to me in taking part in the study as described below:

Purpose: To examine learners' use of navigational maps while studying online text.
Procedure. As a participant you will be asked to:

1) Complete a questionnaire at the beginning of the study.
2) Be set-up on a vision tracker system which will be used to track participants' visual and head movements while they study online text. The equipment consists of a small stationary camera and sensor.
3) Study online text on a given topic.

4) Answer two questions related to the studied text.
5) Answer short questions on their studying experience.

Risks to participants, third party or society: None
***Benefits of the study*:** The study will help inform developers of online materials, on the use and utility of navigational maps and how learners study online content.
Statement of confidentiality: The data of this study will maintain confidentiality of your name and the contributions you have made to the extent allowed by the law.
Interview of employees about their company or agency: This is not applicable.
Inclusion of names of participants in reports of the study: This is not applicable. The researcher will assign an ID number to each participant. All data files will use this ID number to identify the data set.
Contact of participants at a future time or use of the data in other studies: None.

I understand that I may withdraw my participation at any time. I also understand that I may register any complaint with the Director of the Office of Research Ethics.

Director, Office of Research Ethics
8888 University Drive
Simon Fraser University
Burnaby, British Columbia
Canada V5A 1S6
+1 778 782 3447
email: dore@sfu.ca

I may obtain copies of the results of this study, upon its completion by contacting:
Stephanie Chu: stephanie@sfu.ca

I have been informed that the research will be confidential and an ID number is assigned to all data. I understand the risks and contributions of my participation in this study and agree to participate:

Participant First & Last Names
____

Participant Contact Information
____

Participant Signature ____________________________________

Date (MM/DD/YYYY) ____________________________________

APPENDIX C: PARTICIPANT INFORMATION

Participant Information

By filling out this questionnaire, you are agreeing to participate. Please complete every question. There are no right or wrong answers. Responses are confidential and never associated with your name. *You have 10 minutes.*

Section 1

1. *Gender:* ◯ Male ◯ Female
2. *Age* in years:
3. How many course credits/units have you earned at the college and university level? Number of *credits* :
4. What is your intended or declared *major* ? (or "undecided")
5. What is your *GPA* (e.g. 2.35)?
6. At what *age* did you start using a computer?
7. *How often* do you use the internet? [select]
8. Many instructors provide course text to be studied online (e.g. readings, articles, etc. *not* instructions or the syllabus). *How many* of your past courses, have required you to study online readings? Number of courses (if none, enter 0).
9. Compared to learning from print-materials (text-books, articles), *how well* do you learn from online materials? [select]

Section 2

For the following questions, answer each with one sentence. If you do not know the answer, that's okay, you can answer with "*don't know*".

1. What is a *gene*?
2. What are *hybrids* (plant or animal, not cars)?
3. Name one *technique* to create a hybrid plant:
4. Food that is a product or an ingredient made from chemicals or natural resources which have never before been used for nutrition, is *called*:
5. What *technology* comprises all processes in which living organisms or parts of them are used to make products, improve features of plants or animals or develop microorganisms for special usage?
6. In Canada, the regulation of foods is the reponsibility of which *specific group* :

Section 3

For each of the following statements rate how well it describes you when you are learning. *1=completely false and 10=completely true*

#7 Above

[select]
A few times a day
About once a day
A few times a week
About once a week
A few times a month
About once a month
A few times a year or less
Never

9 Above

[select]
I don't learn as well
I learn about the same
I learn better
I haven't tried learning from online materials

Section 3

For each of the following statements rate how well it describes you when you are learning. *1=completely false and 10=completely true*

1: I ask myself periodically if I am meeting my goals.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
2: I consider several alternatives to a problem before I answer.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
3: I try to use strategies that have worked in the past.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
4. I pace myself while learning in order to have enough time.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
5. I understand my intellectual strengths and weaknesses.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
6: I think about what I really need to learn before I begin a task.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
7: I know how well I did once I finish a test.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
8: I set specific goals before I begin a task.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
9: I slow down when I encounter important information.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
10: I know what kind of information is most important to learn.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
11: I ask myself if I have considered all options when solving a problem.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
12: I am good at organizing information.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
13: I consciously focus my attention on important information.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
14: I have a specific purpose for each strategy I use.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
15: I learn best when I know something about the topic.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
16: I know what the teacher expects me to learn.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
17: I am good at remembering information.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
18: I use different learning strategies depending on the situation.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
19: I ask myself if there was an easier way to do things after I finish a task.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
20: I have control over how well I learn.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
21: I periodically review to help me understand important relationships.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
22: I ask myself questions about the material before I begin.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
23: I think of several ways to solve a problem and choose the best one.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
24: I summarize what I've learned after I finish.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
25: I ask others for help when I don't understand something.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
26: I can motivate myself to learn when I need to.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
27: I am aware of what strategies I use when I study.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
28: I find myself analyzing the usefulness of strategies while I study.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10

Continued on next page...

29: I use my intellectual strengths to compensate for my weaknesses.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
30: I focus on the meaning and significance of new information.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
31: I create my own examples to make information more meaningful.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
32: I am a good judge of how well I understand something.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
33: I find myself using helpful learning strategies automatically.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
34: I find myself pausing regularly to check my comprehension.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
35: I know when each strategy I use will be most effective.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
36: I ask myself how well I accomplished my goals once I'm finished.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
37: I draw pictures or diagrams to help me understand while learning.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
38: I ask myself I have considered all options after I solve a problem.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
39: I try to translate new information into my own words.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
40: I change strategies when I fail to understand.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
41: I use the organizational structure of the text to help me learn.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
42: I read instructions carefully before I begin a task.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
43: I ask myself if what I'm reading is related to what I already know.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
44: I reevaluate my assumptions when I get confused.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
45: I organize my time to best accomplish my goals.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
46: I learn more when I am interested in the topic.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
47: I try to break studying down into smaller steps.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
48: I focus on overall meaning rather than specifics.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
49: I ask myself questions about how well I am doing while I am learning something new.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
50: I ask myself if I learned as much as I could have once I finish a task.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
51: I stop and go back over new information that is not clear.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10
52: I stop and reread when I get confused.	○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10

Please ensure that you have responded to all questions. Thank you.

Submit

Appendix D: Free Condition Instructions

Navigation and Viewing Instructions

In the next activity, you will experience a different way of navigating and viewing text. *You control the viewing order.* At the top of each page, you will see an image, while at the bottom, you will see text.

The Image

- Shows you all of the topics.
- Helps you to keep track of where you have been:

  Topic C = topics you have not yet studied. Topic B = the current topic you are studying.
  Topic A = topics you have already visited.

- Is your navigational tool. To navigate, click on a word in a green box. You can only visit a topic once.
- Feel free to navigate to any topic or jump-around: You do not have to proceed in any sequence.

The Text

- Contains 3 sentences on the topic.
- Take your time to study the text. Once you leave the topic, *you cannot go back*.
- Before you leave the topic, rate how well your learning is going at that time.

General Instructions

Study all the topics to prepare yourself for a subsequent test which consists of two questions:

1. Recall everything you remember, including the key concepts and their relationships.
2. Apply what you have learned to a given scenario.

When you are ready, please "start".

Start

Appendix E: Clockwise & Yoked Instructions

The only difference between the clockwise and yoked conditions is the italicized text in second sentence regarding navigational control. For the clockwise condition, it reads, "in *a linear order*."

Navigation and Viewing Instructions

In the next activity, you will experience a different way of navigating and viewing text. You will navigate through the site in a *pre-determined order*. At the top of each page, you will see an image, while at the bottom, you will see text.

The Image

- Shows you all of the topics.
- Helps you to keep track of where you have been:

  Topic C = topics you have not yet studied. **Topic B** = the current topic you are studying.
  Topic A = topics you have already visited.

- Is your navigational tool. To navigate to the *next topic* (see below) , click on the title in a green box. You can only visit a topic once.

The Text

- Contains 3 sentences on the topic.
- Is viewable only once, so take your time to study the text. Once you leave the topic, *you cannot go back*.
- Includes a question asking how well your learning is going at that time.
- Indicates the title of the *next topic* you will study. To navigate, find this topic in the image and click on the title.

General Instructions

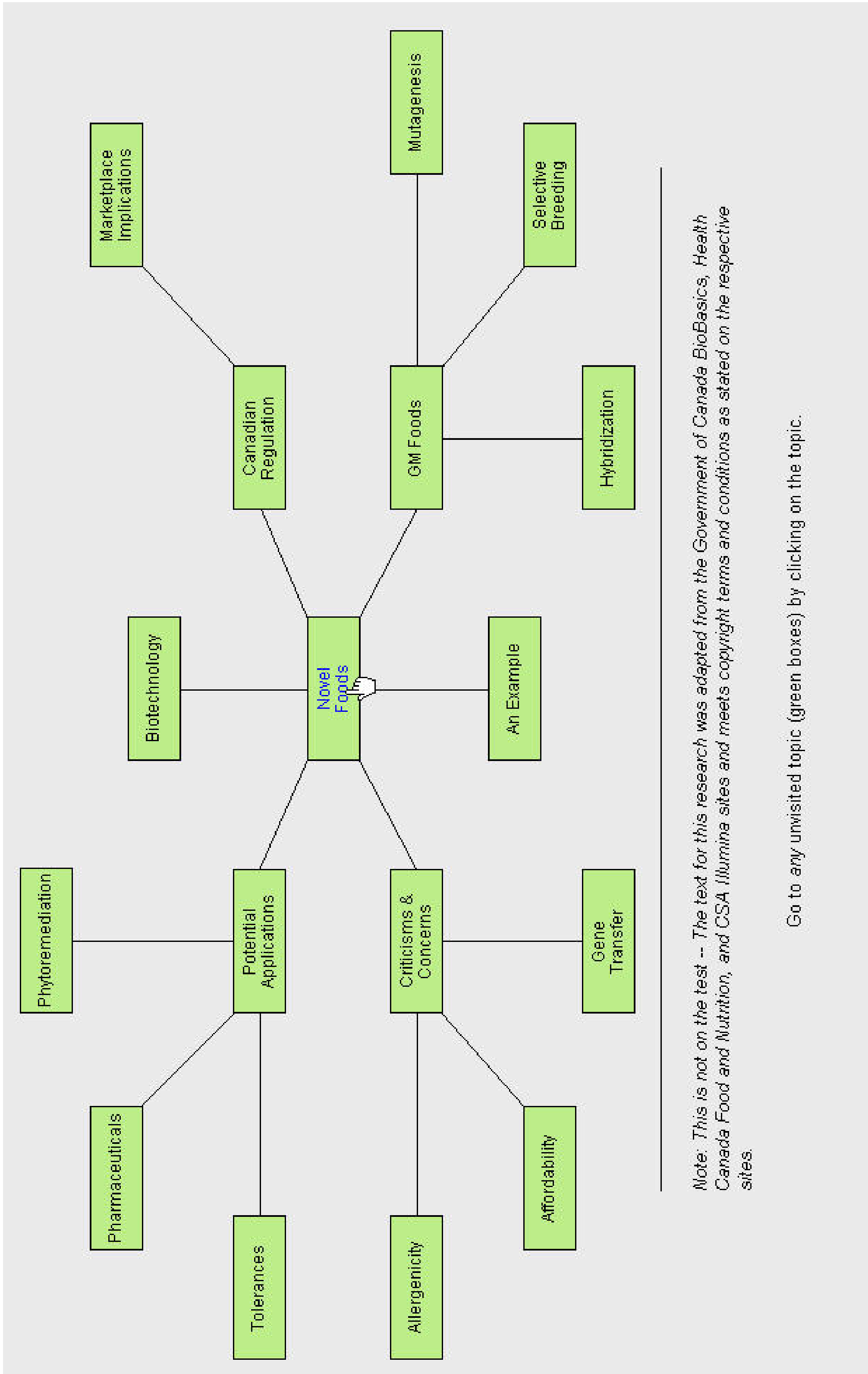
Study all the topics to prepare yourself for a subsequent test which consists of two questions:

1. Recall everything you remember, including the key concepts and their relationships.
2. Apply what you have learned to a given scenario.

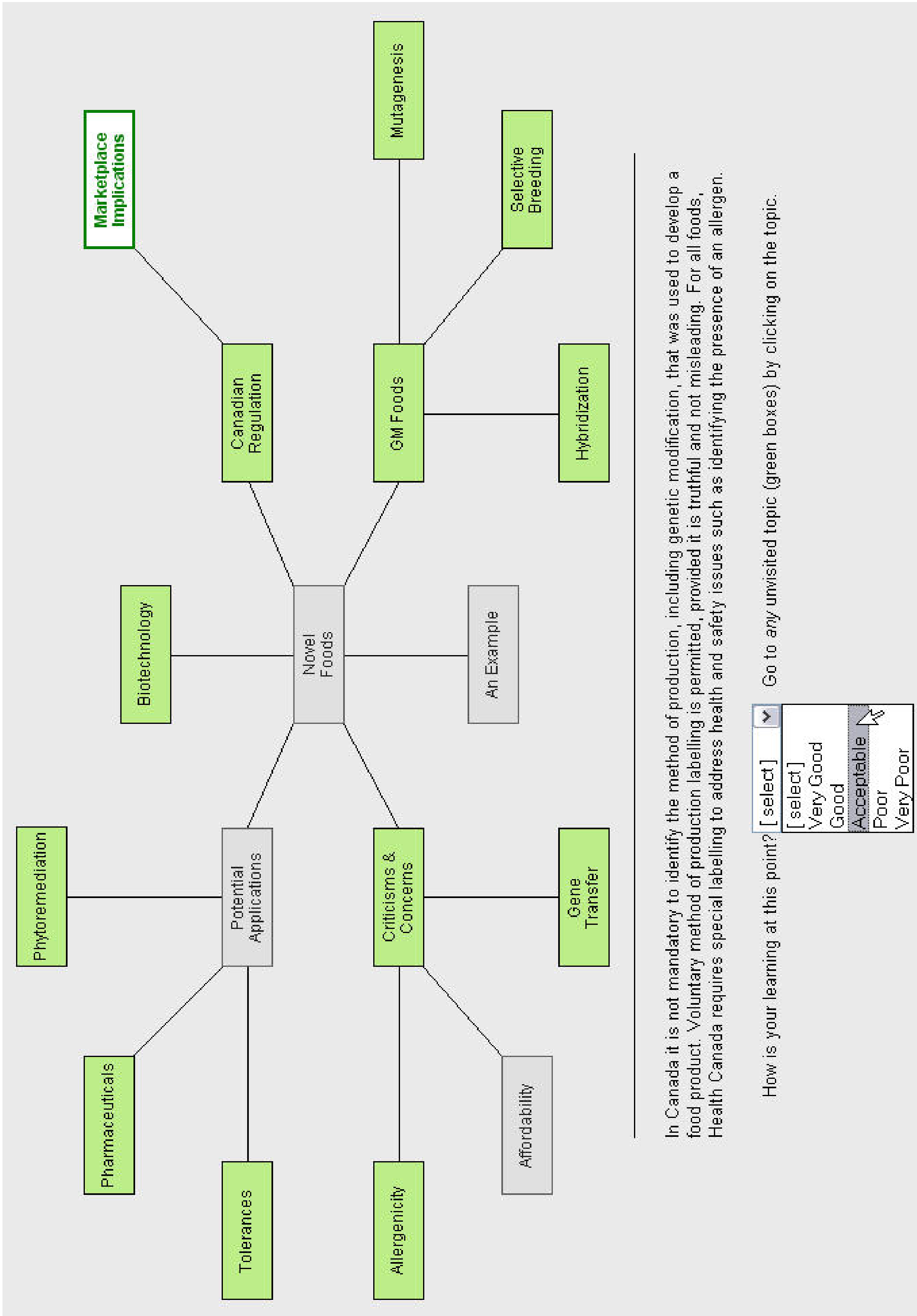
When you are ready, please "start".

Start

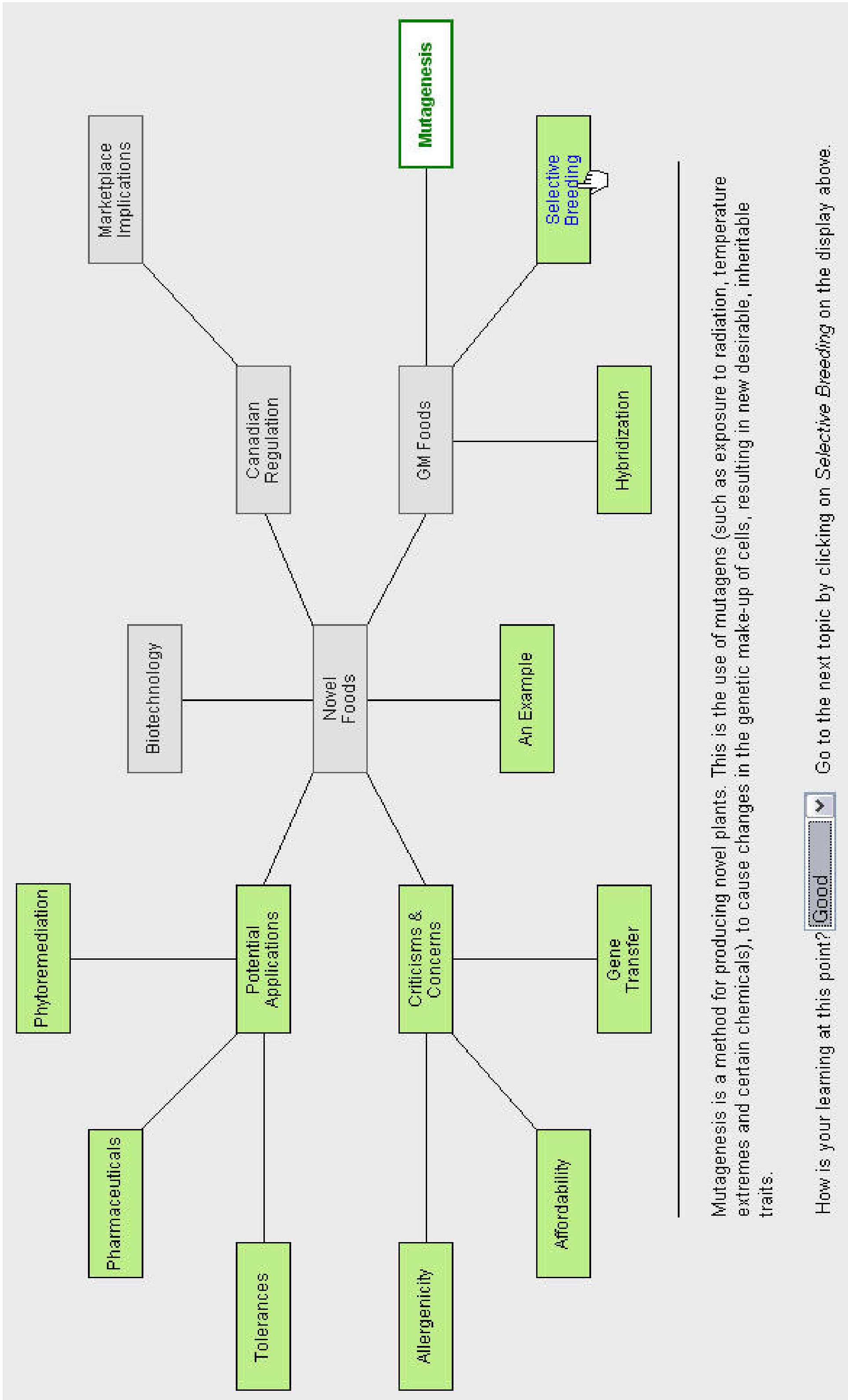
APPENDIX F: START PAGE EXAMPLE (FREE CONDITION)



APPENDIX G: IN PROGRESS EXAMPLE (FREE CONDITION)



APPENDIX H: IN PROGRESS EXAMPLE (CLOCKWISE CONDITION)



Appendix I: Content for Each Page

The eighteen webpages, topics and their related content follow. Total word count of text, excluding the start page: 879 words

Start page [42 words]
Note: This is not on the test -- The text for this research was adapted from the Government of Canada BioBasics, Health Canada Food and Nutrition, and CSA Illumina sites and meets copyright terms and conditions as stated on the respective sites.

Novel foods (50 words)
Novel foods are:

- Foods resulting from a process not previously used for food
- Products that do not have a history of safe use as a food.
- Foods that have been modified by genetic manipulation, also known as genetically modified (GM) foods, genetically engineered foods or biotechnology-derived foods.

Biotechnology (55 words)
Biotechnology involves using living organisms or parts of living organisms towards new methods of production and to create new products. For example, biotechnology uses micro-organisms such as bacteria or fungi to make cheese, ferment wine and beer and make bread. We have also domesticated and selectively bred some animals and plants to meet human needs.

Canadian Regulation (57 words)
The Canadian Food Inspection Agency and Health Canada share responsibility for regulating biotechnology-derived products. It is a 7-10 year process to research, develop, test and assess the safety of a new genetically modified (GM) food. Importers or manufacturers wishing to sell or advertise a GM food must submit data to Health Canada for a pre-market safety assessment.

Marketplace Implications (59 words)
In Canada it is not mandatory to identify the method of production, including genetic modification, that was used to develop a food product. Voluntary method of production labelling is permitted, provided it is truthful and not misleading. For all foods, Health Canada requires special labelling to address health and safety issues such as identifying the presence of an allergen.

GM Foods (54 words)
The term genetically modified (GM) or GMOs (genetically-modified organisms) refers to an organism (e.g. plant, animal or bacterium) where its genetic material has been altered through any method. The most common application is GM crop plants, created

for human or animal consumption. Plants with new traits, not seen in the crop before, are "novel".

Mutagenesis (39 words)
Mutagenesis is a method for producing novel plants. This is the use of mutagens (such as exposure to radiation, temperature extremes and certain chemicals), to cause changes in the genetic make-up of cells, resulting in new desirable, inheritable traits.

Selective Breeding (52 words)
Selective breeding is one method to develop novel organisms. It is the breeding of selected plants and animals to produce offspring with desired traits. The offspring with the desired traits are then used as breeding stock for the next generation and so on, until offspring that express the desired traits are obtained.

Hybridization (47 words)
Hybridization is a method for developing novel plants. This is the production of superior offspring (hybrids) by combining desirable genes from genetically dissimilar parents. This process is used to produce hybrid plants (by cross-breeding two different varieties) or hybridomas (hybrid cells formed by fusing two distinct cells).

An Example (55 words)
Typically, applesauce and other fruit preparations are pasteurized by a heat treatment as a means of inactivating spoilage microbial flora and food-borne pathogens. An approved alternate to heat treatment is high hydrostatic pressure. In this case, the applesauce/fruit blend is deemed a novel food because it resulted from a process not previously used for food.

Criticisms & Concerns (46 words)
Various groups such as environmental activists, scientists and government officials have raised concerns about genetically modified (GM) foods. Agribusiness has been criticized for pursuing profit without concern for potential hazards, and the government for poor regulations. Concerns generally fall into three categories: environmental, health and economic.

Gene Transfer (54 words)
An environmental concern is that crop plants engineered for herbicide tolerance and weeds will cross-breed, resulting in the transfer of the herbicide resistance genes from the crops into the weeds. These "superweeds" would then be herbicide tolerant as well. Other introduced genes may cross over into non-modified crops planted next to genetically modified crops.

Affordability (54 words)
An economic concern is the lengthy and costly process of bringing genetically modified (GM) foods to the market and its impact on consumer prices. Furthermore, many GM plants have been patented, thus consumer advocates are worried that patenting will raise the price of seeds beyond what small farmers and third world countries can afford.

Allergenicity (50 words)
A health concern is the possibility that introducing a gene into a plant may create a new allergen or cause an allergic reaction in susceptible individuals. For example a proposal to incorporate a gene from Brazil nuts into soybeans was abandoned because of the fear of causing unexpected allergic reactions.

Potential Applications (61 words)
The world population has topped 6 billion people and is predicted to double in the next 50 years. Ensuring an adequate food supply for this booming population is going to be a major challenge in the years to come. In addition to making plans more pest and disease resistant, genetically-modified foods aim to meet this need in a number of ways.

Tolerances (56 words)
As the world population grows and more land is utilized for housing instead of food production, farmers will need to grow crops in locations previously unsuited for plant cultivation. Creating plants that can withstand long periods of drought or high salt content in soil and groundwater will help people to grow crops in formerly inhospitable places.

Pharmaceuticals (47 words)
Medicines and vaccines often are costly to produce and sometimes require special storage conditions not readily available in third world countries. Researchers are working to develop edible vaccines in tomatoes and potatoes. These vaccines will be much easier to ship, store and administer than traditional injectable vaccines.

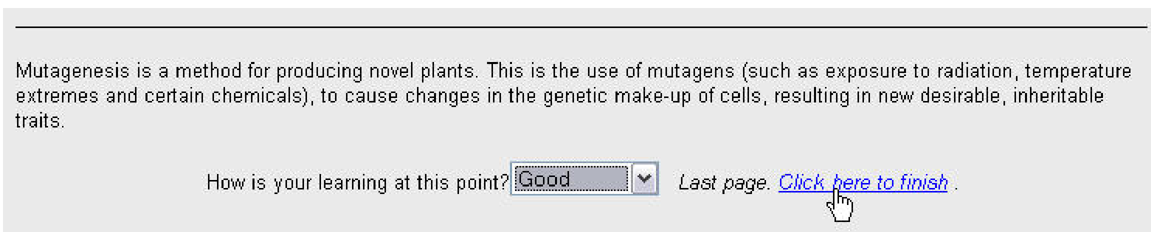
Phytoremediation (43 words)
Not all genetically modified (GM) plants are grown as crops. Soil and groundwater pollution continues to be a problem in all parts of the world. Plants such as poplar trees have been genetically engineered to clean up heavy metal pollution from contaminated soil.

Appendix J: Last Page Examples

The following are examples of the bottom of each condition group's last page.

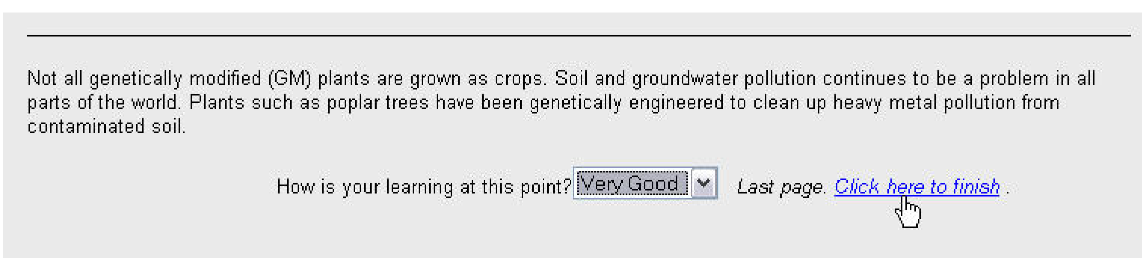
Free and Yoked Conditions

Participants can end on any of the 17 topics. Yoked is based on the sequence of the corresponding free condition (e.g. ID #132 → ID #332).



Clockwise Condition

All participants end on the Phytoremediation page.



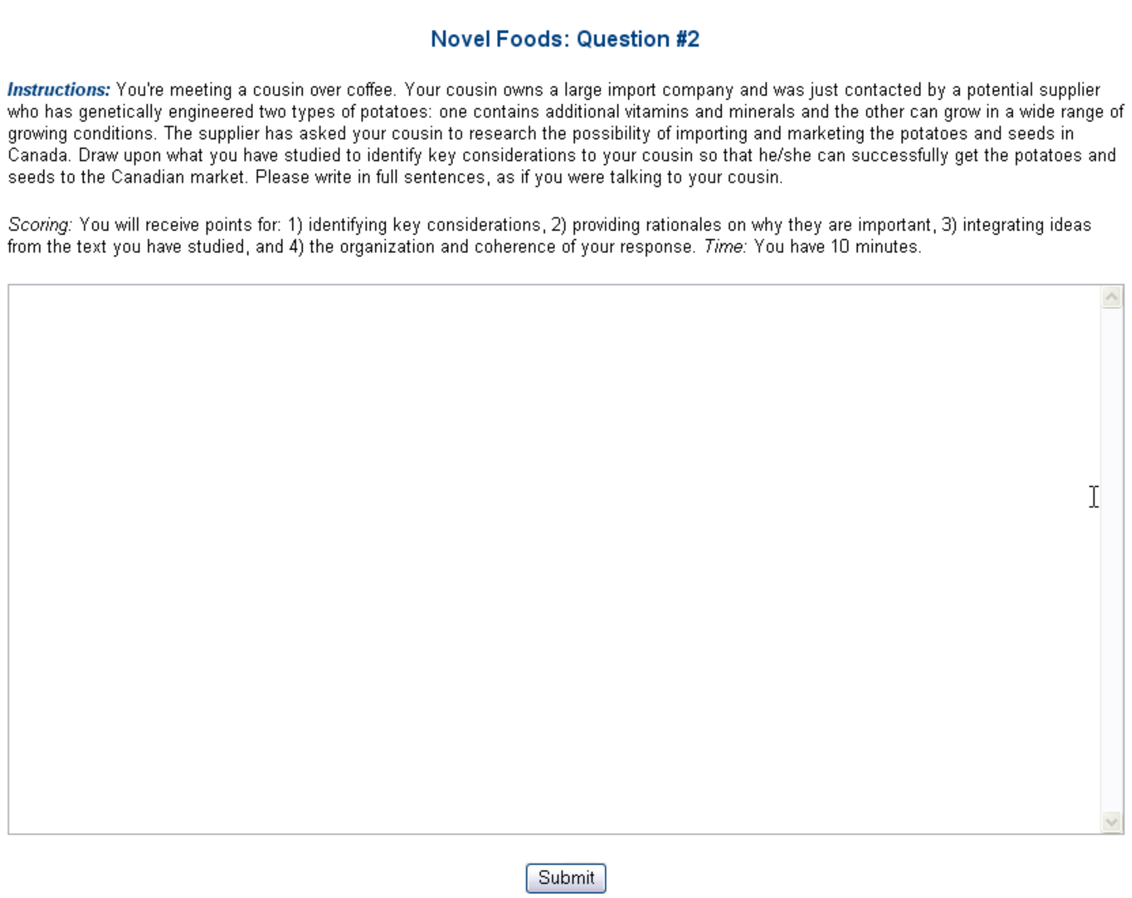
Appendix K: Test Questions 1 and 2

Question 1: Paper-based

Novel Foods: Question #1

Instructions: Please use the space below to show everything you can remember about the text you have just studied. Include key concepts and the relationship between them. Point form, lines, and diagrams are acceptable. *You have 10 minutes. Let the research facilitator know when you are done.*

Question 2: Online



Novel Foods: Question #2

Instructions: You're meeting a cousin over coffee. Your cousin owns a large import company and was just contacted by a potential supplier who has genetically engineered two types of potatoes: one contains additional vitamins and minerals and the other can grow in a wide range of growing conditions. The supplier has asked your cousin to research the possibility of importing and marketing the potatoes and seeds in Canada. Draw upon what you have studied to identify key considerations to your cousin so that he/she can successfully get the potatoes and seeds to the Canadian market. Please write in full sentences, as if you were talking to your cousin.

Scoring: You will receive points for: 1) identifying key considerations, 2) providing rationales on why they are important, 3) integrating ideas from the text you have studied, and 4) the organization and coherence of your response. *Time:* You have 10 minutes.

Submit

Appendix L: Learner's Experience Questions

Final Questions

Section 1: Your studying experience

1. In one or two sentences, *describe* your studying experience?
2. How *motivated* were you to learn at today's session?
   Not at all ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 Extremely
3. How *interested* were you in the topics?
   Not at all ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 Extremely
4. While you were studying, what did you find *easy*?
5. While you were studying, what did you find *challenging*?

Section 2: Today, you experienced a different type of navigational map.

1. How *useful* was the map as a study aid?
   Not at all ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 Extremely
2. Given your rating in #1, explain *why*?
3. What were the map's *strengths* in helping you to study?
4. What were the map's *weaknesses* in helping you to study?
5. *Suggestions* to improve the map so that it is more helpful for studying:

Please ensure that you have responded to all questions. Thank you.

Submit

Appendix M: Payment Received Signature Sheet

Receipt of Payment

Title: Graphical navigational aids (an Online Learning Study)
Investigator Name: Stephanie Chu
Investigator Department: Faculty of Education

This study was designed to investigate learners' use of navigational maps while studying online text. The main benefit of the study is to help instructors with designing useful navigational maps.

If you have concerns about the study, please contact: Dr. Hal Weinberg, Director; Office of Research Ethics (hal_weinberg@sfu.ca)

By signing this document, I agree that I have received $25 for my participation in this study. I understand that if I am one of the three top scorers, I will receive an additional $75 at the end of the study and that I will be contacted via email.

Date: ________________________

Name (print): ____________________________

Email: ____________________________________

Would you like the results of this study emailed to you? _____ Yes _____ No

Signature: _________________________________

APPENDIX N: CORRELATION COEFFICIENT TABLE FOR KEY & COMPOSITE VARIABLES

	Age	GPA	Sex	Credits	Major	Comp. Age	Internet	# Online	Learn Online
Age	1.00								
GPA	-.26*	1.00							
Sex	.44	-.10	1.00						
Credits	.45***	.17	.12	1.00					
Major	.12	.10	.11	.22	1.00				
Comp. Age	.49***	-.40***	.09	.02	.05	1.00			
Internet	-.27	.25	-.02	.06	.08	-.23	1.00		
# Online	-.07	.04	.24	.32**	-.07	-.02	.13	1.00	
Learn Online	.06	.09	.03	-.07	-.20	-.10	.01	.31	1.00
Prior Know.	.16	.20	-.10	.22	-.05	-.12	-.07	-.04	-.04
Know of Cog.	-.31*	.45***	-.00	.05	-.02	-.21	.11	-.02	.15
Reg. of Cog.	-.39**	.27*	-.01	.05	-.06	-.28*	.02	.01	.05
Condition	.16	-.18	-.04	.14	.02	.03	-.18	.10	.01
M Rate Learn	.11	.17	-.08	.19	-.09	-.04	.07	.08	.14
Time on Map	.09	.06	.15	.06	-.22	.22	.30	-.01	-.03
Time on Text	.14	-.21	.30	.30	-.12	.53	-.16	.23	-.14
Tot. Time Study	-.10	-.02	.31	.13	.13	.18	.02	.13	-.16
Time Not Fix.	.16	-.12	.15	.42	-.02	-.01	-.13	.09	-.14
Fix. Act. Start Pg.	.08	-.04	-.05	-.01	-.27	-.19	-.14	.02	.27
Fix. Act. 1st 1/3	-.06	-.11	-.07	-.04	.00	.05	.02	.08	.18
Fix. Act. 2nd 1/3	.18	-.08	.16	.22	.06	-.18	.11	.20	.10
Fix. Act. 3rd 1/3	.04	.16	-.14	-.05	-.05	-.19	-.01	.19	.20
Fix Act. Final P.	.23	-.08	.14	.20	.08	.09	-.18	.13	.28
Tot. # Fix. Map	.10	-.01	.48	.06	-.21	.07	-.21	-.02	.00
Tot. # Fix. Text	.06	-.14	.29	.36*	-.13	.25	.09	.38	-.05
Tot. # Fix.	.11	-.12	.32	.38*	-.11	.25	-.02	.35	-.03
Distinct Map Tot. #	-.04	-.09	-.08	-.11	-.20	.02	.01	-.02	-.13
Distinct Text Tot. #	.07	-.20	-.22	.10	-.01	-.00	-.05	-.01	-.18
Ave. Fix. Duration	.09	-.15	.24	-.06	.03	.60*	-.32	-.10	-.21
Recall	-.10	.45***	-.14	.17	.19	-.26*	.17	,03	-.28*
Application	.03	.26*	-.17	.17	.19	-.16	.15	.09	-.08
Map Utility	.17	.13	.08	.12	-.08	.16	-.04	.00	.06
Interest	.17	.04	-.15	.19	-.30	.01	-.05	.19	-.04
Motivation	-.07	.20	.02	.05	-.05	.04	.03	.00	-.10

	Prior Know.	Know. of Cog.	Reg. of Cog.	Condi-tion	*M* Rate Learn.	Tot. Map Time	Tot. Text Time	Tot. Time Study	Time Not Fixated
Prior Know.	1.00								
Know of Cog.	.08	1.00							
Reg. of Cog.	.02	.81***	1.00						
Condition	-.07	-.26	-.02	1.00					
M Learn. Rate	.25*	.37**	.21	.03	1.00				
Total Map Time	.13	.09	.17	-.31	-.15	1.00			
Total Text Time	-.29	-.04	-.12	.11	-.19	-.04	1.00		
Tot. Time Study	-.28	.07	.09	-.06	-.30*	.49**	.71***	1.00	
Time Not Fix.	-.16	-.10	-.13	.13	-.26	.31	.24	.61***	1.00
Fix. Act. Start Pg.	.08	.24	.24	.14	.05	.15	.15	.06	.13
Fix. Act. 1st 1/3	-.07	-.12	.06	-.08	-.22	.45**	.13	.32*	.30
Fix. Act. 2nd 1/3	.10	-.12	.13	-.23	-.19	.44**	-.23	.13	.34*
Fix. Act. 3rd 1/3	.24	.05	.22	-.14	-.12	.46**	-.33	.07	.26
Fix Act. Final P.	.07	-.15	-.00	-.06	-.19	.46**	-.18	.10	.11
Tot. # Fix. Map	.20	-.01	.16	.14	-.17	.89***	-.13	.34*	.41*
Tot. # Fix. Text	-.18	.04	-.03	.21	-.13	.00	.85***	.57***	.33
Tot. # Fix.	-.08	.03	.04	.12	-.18	.38*	.70***	.66***	.48**
Distinct Map Tot. #	.05	.06	.18	-.40	-.16	.54***	-.03	.30	.58***
Distinct Text Tot. #	-.11	-.14	.05	-.02	-.36	.29	.04	.47	.82***
Ave. Fix. Duration	-.23	-.11	-.22	-.22	-.25	.13	.48**	.50**	-.07
Recall	.34**	.26*	.12	-.24	.19	.22	-.27	-.01	.01
Application	.24	-.01	-.15	-.02	.17	.15	-.28	-.09	-.09
Map Utility	.17	.12	.20	-.19	.15	.41	-.29	.00	.05
Interest	.12	.10	.10	-.03	.19	.17	.06	-.25	.35*
Motivation	.32*	.50***	.32**	-.18	.45***	.15	.11	-.08	.21

	Fix. Activity Start P.	Fix. Act. 1st 1/3	Fix. Act. 2nd 1/3	Fix. Act. 3rd 1/3	Fix. Act. Final Pg.	Tot. # Fix. Map	Tot. # Fix. Text	Tot. #. Fix.
Fix. Act. Start	1.00							
Fix. Act. 1st 1/3	.46**	1.00						
Fix. Act. 2nd 1/3	-.04	.22	1.00					
Fix. Act. 3rd 1/3	.20	.24	.60***	1.00				
Fix. Act. Final P.	.05	.18	.30	.32	1.00			
Tot. # Fix. Map	.28	.57**	.56**	.57**	.49**	1.00		
Tot. # Fix. Text	.24	.25	.00	-.12	-.14	.02	1.00	
Tot. # Fix.	.34*	.47**	.34*	.14	.09	.44**	.70***	1.00
Distinct Map Tot. #	.15	.49**	.54***	.55***	.05	.68***	.15	.41*
Distinct Text Tot. #	-.02	.27	.38	.37*	.01	.38*	.11	.26
Ave. Fix. Duration	-.12	-.18	-.36*	-.31	-.01	-.16	-.01	-.07
Recall	.01	.05	.27	.21	-.09	.27	-.01	.10
Application	-.26	-.18	-.01	.04	.24	.17	-.10	-.02
Map Utility	.11	.25	.30	.33*	.49**	.45**	-.17	.05
Interest	-.01	-.01	.17	-.05	.04	.24	.29	.35*
Motivation	-.12	-.26	-.04	-.08	-.21	.10	.19	.21

	Distinct Map. Tot. #	Distinct Text Tot. #	Ave. Fix. Duration	Recall	Applica-tion	Map Utility	Interest	Motiva-tion
Distinct Map Tot. #	1.00							
Distinct Text Tot. #	.76**	1.00						
Ave. Fix. Duration	-.24	-.09	1.00					
Recall	.33	.04	-.40*	1.00				
Application	-.07	-.19	-.23	.59**	1.00			
Map Utility	.33	.12	-.22	.29*	.23	1.00		
Interest	.18	-.11	-.35*	.46*	.41**	.39**	1.00	
Motivation	.10	-.15	-.07	.29	.46**	.28	.42*	1.00

* $p < .05$, * $p < .01$, *** $p < .001$
Spearman's Rho → internet use, learning online, average self-rating on learning, fixation activity on a) start page, b) first 1/3, c) second 1/3, d) final 1/3, e) final page; map utility rating, self-reported interest, self-reported motivation, sex, major, condition
Pearson's correlation → all other variables

Appendix O: Standardised Scatterplot & P-P Plot for Self-Ratings on Learning

Figure A: Distribution of residual scores for ratings on learning.

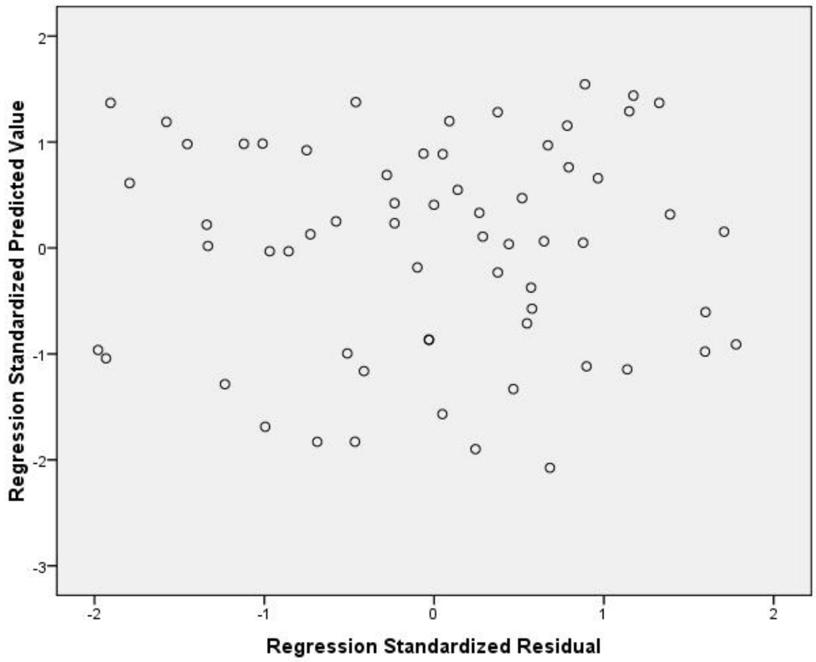
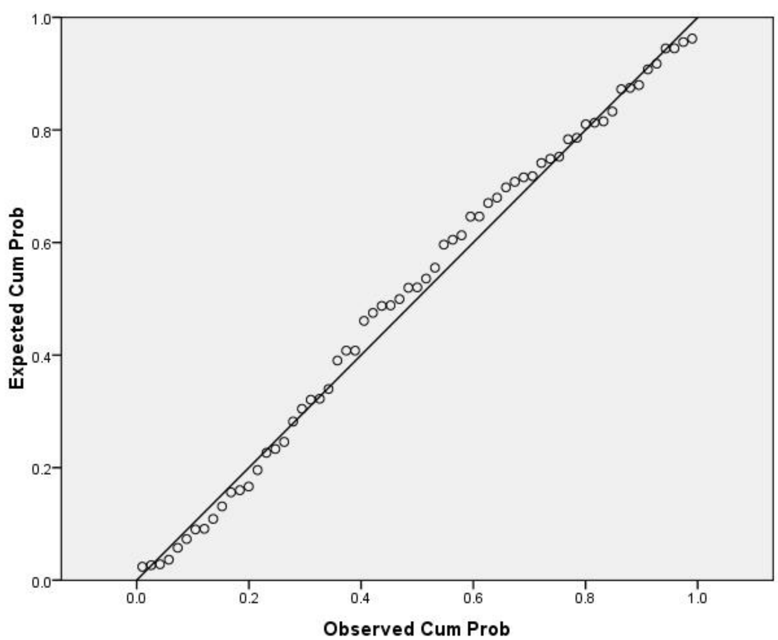


Figure B: P-P plot of the regression solution for ratings on learning.



Appendix P: Standardised Scatterplot & P-P Plot for Recall Scores

Figure C: Distribution of residual scores for recall scores.

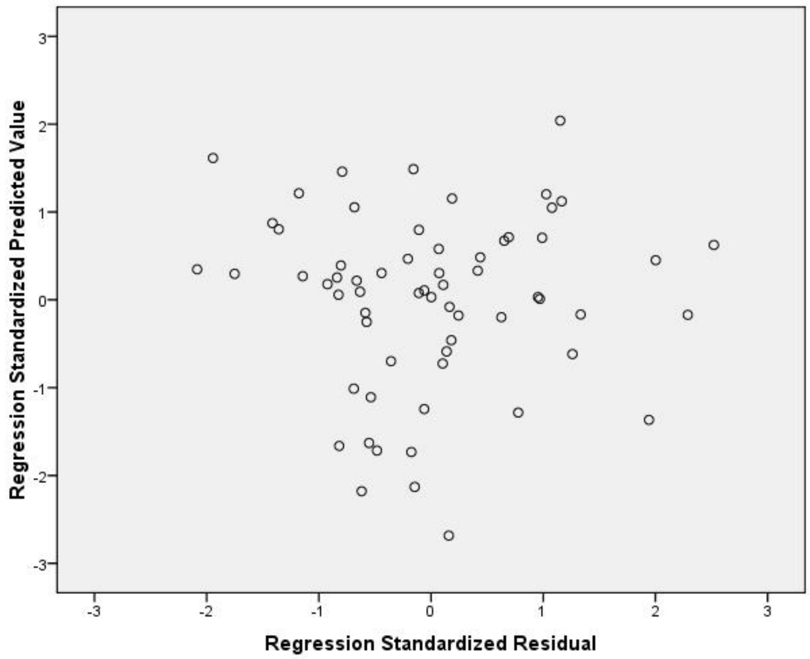
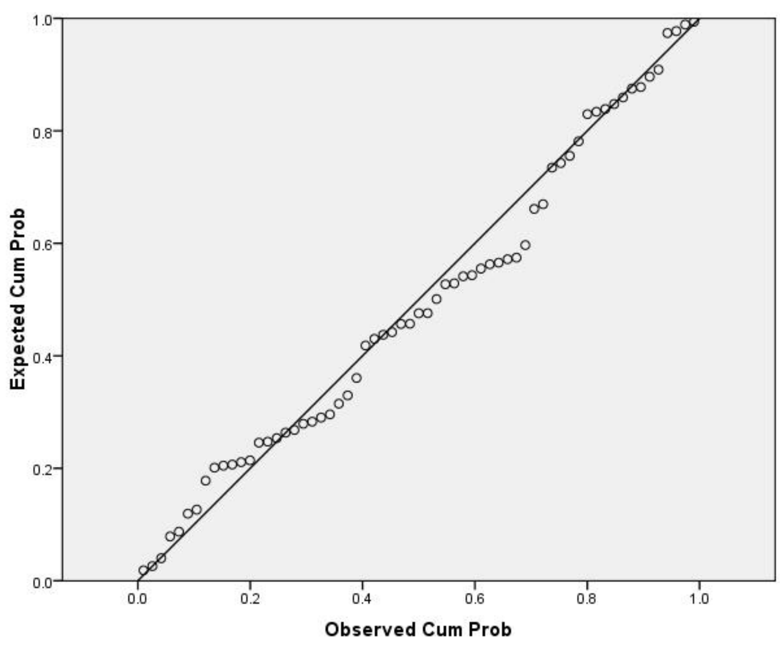


Figure D: P-P plot of the regression solution for recall scores.



Appendix Q: Standardised Scatterplot & P-P Plot for Application Scores

Figure E: Distribution of residual scores for application scores.

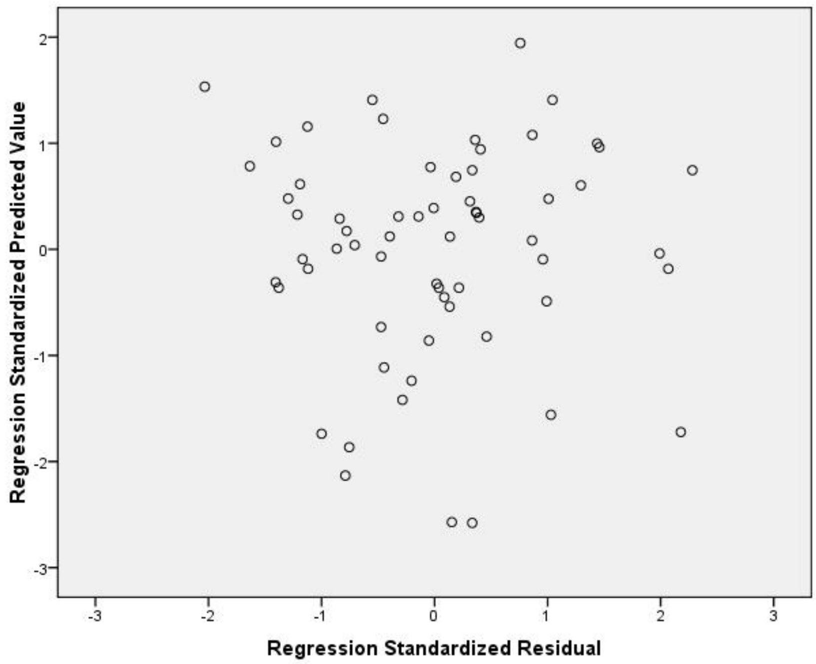
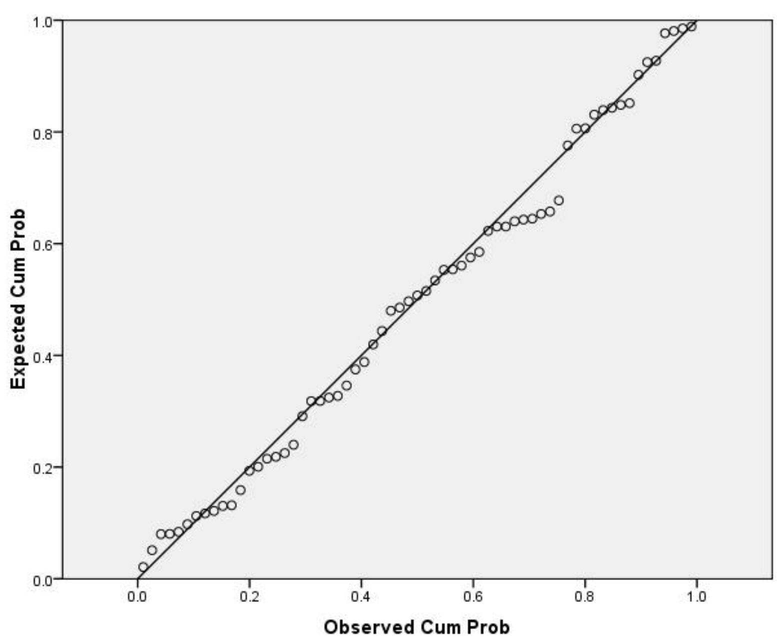


Figure F: P-P plot of the regression solution for application scores.



Appendix R: Studying Experience Description

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Chunking of content (1-1-0)	▪ It was nice the information was presented in small amounts (110)	▪ I think the format of the web page helped be group key concepts better than if reading a manuscript (204)	
Content length and amount (6-1-2)	▪ It was long (101) ▪ There are a lot of information to consume (108) ▪ There was a lot of information presented (109) ▪ A lot of different ideas that were tied into 3 main themes (109) ▪ difficult to remember specific details that did not seem all that relevent to understanding the general concept (109) ▪ Too much information to remember in 10 minutes (120)	▪ Near the end, it was quite over-whelming (212)	▪ the information/study material was a bit overwhelming (309) ▪ The layout of the parts didn't seem logical (312)
Level of prior knowledge (3-2-4)	▪ [It was a] new topic (101) ▪ I don't know much about novel food (108) ▪ I am not very good at biology and genetics (115)	▪ I knew the topic (206) ▪ This was a new subject area for me (210)	▪ it's a topic I know little about (302) ▪ this is a topic I am not familiar with (307) ▪ I learnt some of the information about GM food in my high school time (308) ▪ very new to me (316)
Topic interest (2-2-5)	▪ I found the material easy and informative (106) ▪ It was an interesting topic and enjoyable to learn (117)	▪ Biology part was very intersting to learn (203) ▪ Very informative and interesting (215)	▪ It is very informative and provies me the other aspects of GMO (Novel) Foods (305) ▪ I found out a lot of new and interesting things (306) ▪ this studying session gave me an updated review (308) ▪ It was very informative and kind of enjoyable actually (317) ▪ The experience was

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
			informative and interesting (318)
Control over navigation: Choice (2-0-0)	▪ I liked having free range of choosing which topic to review (111) ▪ I liked how I was able to choose where I could start studying and which topics to continue with so the text wasn't all over the place (112)		
No control over time (2-3-4)	▪ It was a bit different because I knew I was under a short time constraint (116) ▪ I had only 10 minutes to study the material (119)	▪ there is also time limit during the studying (202) ▪ it would have been better if I were to have more time to study. 10 minutes is very limited time (203) ▪ 10 minutes was a bit short for me (216)	▪ There was time pressure (301) ▪ rushing to complete the reading in 10min. (303) ▪ (nervous or pressured due to) time constraint (304) ▪ ...such a short time) (313)
Restricted navigation & strategy use: Review (2-1-1)	▪ I would have liked to go back and re-read some of the topics to understand them more fully (102) ▪ normally i would go back and review things (110)	▪ I think it would have been more beneficial if the option of revisiting the notes were available -based on my study habits (217)	▪ I wasn't allowed to revisit the pages I've already read (301)
Unable to implement own learning strategies (2-5-5)	▪ Different from my desired method of studying (104) ▪ I can't use my own studying methods (when in this environment) (107)	▪ It usually takes me some time to understand the setences if I be assigned to read a long article (201) ▪ this studying experience is quite different from what I usually do for studying (202) ▪ it doesn't allow me to take note while reading the materials (202) ▪ Different as I am usually taking notes on the side to help me remember key facts (208) ▪ I usually take a long time to study material (216)	▪ It was very different from how I usually study (301) ▪ Pictures would have been useful as well (310) ▪ uncomfortable to study without taking notes (311) ▪ [uncomfortable] with someone else's breakdown of topics. (311) ▪ For me, making the breakdown myself it usually where half my learning comes from (311)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Learning using the map: Positive (6-7-4)	▪ seemed to make studying much easier (104) ▪ visual aspects of the study helped in remembering the concepts (105) ▪ (helped) in organizing the concepts (105) ▪ really enjoyed learning non-linearly from the chart (106) ▪ It wAS EASIER FOR ME TO LEARN THAT WAY (106) ▪ it was a fun way of visualizing / characterizing the information (114)	▪ [format] made it slightly more enjoyable (204) ▪ I enjoyed the mapping of ideas (205) ▪ (enjoyed) how each key word gave an indication of what was going to be presented in further detail (205) ▪ The visual map paired with the short text made connecting ideas easier than if I had simply been reading paragraphs (209) ▪ I found it was quite interesting and an enjoyable technology (211) ▪ seeing the visual map of the concepts and going through it was a definite help to learning the concepts (211) ▪ It is good to have a diagram illustrating the relationship of a main topic with other subtopics (219)	▪ It began well while I was reading the diagram (302) ▪ [did not pay enough attention to the image)<concept map>, which would have been very useful (303) ▪ I thought the diagrams were a useful tool in addition to the text because it helped organize information understand what the topic was about (310) ▪ The diagram did help put together the relationships (313)
Learning w/ the map: Neutral (0-0-1)			▪ Overall midrange of ease of use (312)
Learning using the map: Negative (1-0-1)	▪ having to move the eyes from all over the screen to the bottom (where the text was smallish) made my eyes tire really fast (114)		▪ i would expect a more linear style for this type of learning (312)
Self-reflection / approach to studying (1-5-4)	▪ I read everything over once, but I should have read it twice (113)	▪ I went a little faster then I should have (206) ▪ Slow at the beginning and rushed at the end (213) ▪ I read each section and through using the image created short sentences which described the relationship between the different sections (218) ▪ I also tried to make lists from each topic, like the 3 ways of causing mutagenesis (218) ▪ I realized that I have to consider my time when doing certain tasks (221)	▪ I did not pay enough attention to the image<concept map> (303) ▪ I had to go over the information twice to understand and soak in what I was reading (320) ▪ My studying experience will be very rough, ineffective yet sometimes can be improved (321) ▪ I am too afraid of getting bad grades and anxiety interferes with my academic performances (321)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Learning in general: Positive (6-6-6)	▪ was able to get an idea about the topic (101) ▪ very quick and simple (103) ▪ it is good to learn something in a short period of time (108) ▪ overall it was interesting (116) ▪ very good, enjoyed it. ▪ It was fun and interesting to do (119)	▪ Was very good (203) ▪ it was in general interesting and fun (207) ▪ It was good (210) ▪ finding out about my learning retention, it was great! (210) ▪ It was an interesting experience (214) ▪ Very good (220)	▪ I enjoyed it (304) ▪ I found my studying experience to be very enlightening (306) ▪ as I read on, I started to get the hang of it (307) ▪ It was good (311) ▪ I remembered mostly what I studied in the beginning (314) ▪ I feel as though I have associated with the information well (315)
Learning in general: Neutral (3-1-1)	▪ It was not too stressful (102) ▪ Fairly straight forward (109) ▪ The experience was okay (121)	▪ My studying experience was okay (217)	▪ You need to have a great ability to memorize all the information in just 10 minutes. It is not a easy or hard task (319)
Learning in general: Negative (5-1-9)	▪ had [a] little difficulty in grasping the new knowledge (101) ▪ quite difficult for me (107) ▪ I found it difficult (110) ▪ My studying experience did not go that well (115) ▪ I was a bit nervous (119)	▪ Not very interactive (207)	▪ I wasn't able to learn and remember much (301) ▪ it was difficult to remember everything (302) ▪ I found myself forgetting the earlier facts after reading more (303) ▪ I did feel nervous or pressured (304) ▪ It was quite intense in the beginning (307) ▪ I don't think I absorbed that much of the material (in such a short time) (313) ▪ could not recall as much information from the end of the information graph (314) ▪ I had difficulty recalling ALL of it when asked (315) ▪ It was very trying (320)
Environment: Positive (0-1-1)		▪ nice atmosphere not too much pressure (220)	▪ it was kind of easy to forget that I was in a monitored environment, so the process felt natural (317)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Environment: Negative (2-0-2)	▪ (can't use my own studying methods when) I'm in this environment (107) ▪ was not in ideal conditions (121)		▪ (nervous or pressured due to) the experimental environment at times (304) ▪ It was just a bit distracting to be in this environment as I found myself sometimes interested by the movement of the camera, or by keeping my pose (315)
Task Definition (2-2-1)	▪ My studying experience was mostly reading (113) ▪ different in the sense of using a camera to note eye movement (118)	▪ I had to retain lots of different facts in a very limited time and (214) ▪ then relay them (facts) both as facts themselves and use them in a specific situation (214)	▪ My studying experience involved reading text, viewing diagrams, and answering questions (310)

* Notes: Aside from text in brackets, which were added to provide context, statements are verbatim. Numbers in brackets under the category topic indicate the number of statements per condition group in the order presented by the columns. Bracketed numbers beside statements are the participants' IDs.

Appendix S: Studying Experience Ease

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
General format (5-5-1)	▪ Short sentences (101) ▪ wording was simple and not complicated (102) ▪ THE SENTENCES WERE SHORT, INFORMATIVe and spaced out nicely (106) ▪ I found the layout easy to understand (113) ▪ Things that made sense (120)	▪ The flow of the reading was easy (208) ▪ The text at the bottom was concise and got to the point, making it easy to follow (209) ▪ the small amount of text was good too (210) ▪ The user interface (211) ▪ I liked how the text was broken down into three sentences per topic. It made it very concise (215)	▪ Something it is easily making sense to me (321)
Map in general (3-2-0)	▪ web map made it easier to study the topic (107) ▪ the diagram helped a lot (110) ▪ The use of the flow chart/web diagram made it easier to understand the material (119)	▪ The use of visuals! (210) ▪ The layout of the diagram (221)	
Topic interest / relevancy (1-1-2)	▪ I found the fact that I was studying an interesting, up-to-date subject easy (117)	▪ The information that I think is more relevant to me (212)	▪ Reading facts including numbers (314) ▪ real world examples easy, such as the pros, cons, and possibilities of releasing GM foods to the public (315)
Content's level of difficulty (1-3-4)	▪ The information that was presented was not very challenging to grasp (109)	▪ The parts which are not related to that expert field (201) ▪ The non-science related stuff, especially non-science definitions (207) ▪ the concepts [was] pretty easy (211)	▪ I found the general information about the concerns and such easier to follow than the actual scientific definitions of processes (like mutegenesis) (302) ▪ The text on each topic was easy to comprehend (304) ▪ The definations of specific wordings (308) ▪ understanding the general topics (312)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Having prior knowledge (6-4-4)	▪ I found terms and ideas I already knew easy (103) ▪ I have taken a course in nutrition before, so some of the information is vaguely familiar (109) ▪ items that were in the press and that I've already heard / seen (114) ▪ Some things I already knew, so theose were the easiest parts (115) ▪ This topic or related topics are often in the news (117) ▪ things that I have experience with (120)	▪ Alot of these terms, general public hears it in the news. So any public terms that people are farmiliar with (203) ▪ The information that i already knew something about like biotechnology (213) ▪ I had some background on the topic I was reading so I could relate more easily and therefore understand the topic more (217) ▪ Memorizing topics that I could relate to (220)	▪ Some topics that I already knew or have done researches on them (305) ▪ I found it easy to understand topics that came up in previous Bio classes that I took before. That was a few years ago, but reading about the keywords and concepts rang a bell (310) ▪ This is because I had already kind of known the terms ahead of time (313) ▪ something I can predict (321)
Topic specific (4-2-4)	▪ all the different methods in which the food could be modified to maintain given traits (104) ▪ Criticism and regulations concerning the GM foods (105) ▪ The marketing related things because I can relate to it (108) ▪ I found the practical applications and concerns about the topic the easiest to remember and understand (121)	▪ Some terms like biotechnology, genetics and genetic engineering (203) ▪ about all the topics were easily understood, but the genetically modified organisms were easy (206)	▪ I found that the topic relating to the uses of novel foods easy relative to the other topics (307) ▪ I thought the things about genetically modifed foods was easier than the rest. Also, I found the part about the regulations on the foods was ok. (313)
Identifying links or relationships (1-5-3)	▪ I found it easy to link the ideas (110)	▪ The mapping and the diagram helps to learn and to gain understanding in the topics (202) ▪ rememeber the relationships between sections was easier to remember (208) ▪ I found the diagram to be quite helpful because it showed the relationship between the topics I was studying (216) ▪ to remember the simple relationships between concepts, like what are 3 possible concerns with GMO foods (218) ▪ The relationship between	▪ It was also easy in the sense that there was a diagram set out, broken down into smaller and smaller groups (302) ▪ remember them as leading into the next using the arrows on the map. Eg: Novel Foods lead to GM foods which lead to methods of creating GM foods (317) ▪ when the words were linked to each word, so you could memorize or store the information as knowledge easier (319)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
		topics is the easiest to memorize (219)	
Identifying topics (2-2-2)	▪ easy to identify the major topics of the information i.e. Background information, applications, criticisms/concerns and regulation of GM foods (109) ▪ (easy to) see what I wanted to learn next (116)	▪ The key concepts and words were easy because very directly arranged (204)	▪ Remembering the key words/terms because they "stood out" from everything else (301) ▪ To organize thoughts under key headings (317)
Knowing one's location (0-0-1)			▪ how i can keep track of where i am in this study (316)
Navigation (3-0-3)	▪ I found it easy to make coherent 'paths', moving from one topic to the next which actually helped me to remember the different areas (111) ▪ How you could choose a category, and then after reading the category, choose the sub-categories (112) ▪ easy to navigate (116)		▪ Navigating was easy (303) ▪ switching between the topics (312) ▪ Clicking through the questions (318)
Process (0-3-2)		▪ I found the points towards the end easier to study, as I developed an understanding of how the material was laid out (205) ▪ the directions were quite clear (211) ▪ Reading through them and absorbing the information seemed easy (214)	▪ I found it easy to read the instructions and learn a few things (306) ▪ Understanding the concepts while they were in front of me (311)

* Notes: Participants #118 and #309 did not answer the question in a manner that provide data for this table and #320 reported that nothing was easy. Aside from text in brackets, which were added to provide context, statements are verbatim. Numbers in brackets under the category topic indicate the number of statements per condition group in the order presented by the columns. Bracketed numbers beside statements are the participants' IDs.

APPENDIX T: STUDYING EXPERIENCE CHALLENGES

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Content's level of difficulty (0-0-1)			▪ Reading complicated sentence structure or words slowed me down, causing me to read and reread sentences (314)
Topic disinterest / lack of relevancy (3-0-2)	▪ this isnt my area of interest (107) ▪ I had a hard time retaining information because I was not interested enough (115) ▪ Things that do not affect me (120)		▪ The diagram headings were usually jargon terms which made the diagram not very useful (304) ▪ the topic is not really of my interest, so it is a little unmotivating to keep going to me (321)
Information overload / retention (3-4-1)	▪ there was too much information that I…had to think hard about, in most of the sentences (106) ▪ the amount of information that was presented (109) ▪ to learn many small pieces of information at a short time (116)	▪ so many different sections. (208) ▪ retaining the information after some time has passed and I kept reading new information at the same time while trying to retain the older information (214) ▪ separated contents and many information about the main topic (219) ▪ The overloading information (221)	▪ a lot of information to take in (306)
Study set-up effects (2-0-1)	▪ I continued to forget to click on the box that asked how well I understood the information, and then once I tried to click something else but was stopped, so was my train of thought (111) ▪ I found reading on this moniter to be challenging (113)		▪ (after studying) right away write it all out from what you remember (319)
No control over navigation: Choice (2-0-3)	▪ I would have preferred if there was an order to which topic to go to next; the ability to choose which topic to view, or learn about first, is something I am not used to (102) ▪ Deciding where to begin		▪ it seemed like the order in which we went through the topics was scrambled (304) ▪ being unable to choose my own topics)316) ▪ how the topics change (316)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
	reading was a challenge (119)		
No control over learning strategy use: Notes (2-1-0)	▪ especially without writing it down (therefore I had to read a few times to absorb) (116) ▪ to remember everything without being able to take notes (117)	▪ when I study I like to take notes and not being aabel to take notes (216)	
No control over time (1-4-3)	▪ the time constraints (110)	▪ time restraint was limited (203) ▪ time constraints of the study (210) ▪ time limit was a bit too short for my learning style (216) ▪ need to learn in a small fixed about of time (221)	▪ so little time (306) ▪ such a short time (309) ▪ you had to memorize the information in 10 minutes (319)
Restricted navigation & strategy use: Review (5-3-3)	▪ If I have been able to go back to the previously studied topic I would have been able to relate topics better (101) ▪ Not being able to go back to topics (102) ▪ It was hard because I could not re-visit areas that I had forgotten about later (109) ▪ Normally i would go once through to get the general idea then go back to confirm the details (110) ▪ to remember everything without being able...go back to topics previously viewed (117)	▪ would have like to be able to review everything with all the text in one page at the end (215) ▪ I couldn't revisit topics I had covered previously (216) ▪ I couldn't revisit the information and that I was required to memorize all the information presented once (217)	▪ wasn't able to go back to a topic in order to draw connections between it and something I had just finished reading (302) ▪ Remembering the concepts after the page changed and the topic was gone (311) ▪ you could only read it once or twice and you cannot go back to it (319)
Not understanding the purpose / task (0-2-1)		▪ I did not know what was the goal of studying the materials was (205) ▪ I did not know what was going to be tested on (205)	▪ Found it challenging to know what to concentrate on, since I had no idea what kind of questions were ahead - would I have to define things, or multiple choice, or draw on general themes, etc. (317)
No additional learning aids (0-0-1)			▪ Visual aids may have helped (310)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Not having prior knowledge (7-6-2)	▪ difficult for me to relate them to any other information I had from before (105) ▪ there was too much information that I didn't know about (106) ▪ I cant relate it to anything that I've learnt elsewhere - in a sense, I dont have any foundation to build upon (107) ▪ Those biology terms because I don't recognize them at all (108) ▪ the real heavy biology terminology, i only really learned the examples and not the academic terms (114) ▪ things that I do not know (120) ▪ names or terms I hadn't heard before (121)	▪ parts when it started to get deeply into the expert field (201) ▪ New terms and some wording in research (203) ▪ some of the scientific jargon (204) ▪ The terminology (210) ▪ The technical terms that were introduced and concepts that we wouldn't normally come across in everyday life (212) ▪ to remember specific terms which I had not encountered before, such as what it;s called when a plant can purify the environment, top left (218)	▪ Technical (Biological) terms that I am not familiar with (305) ▪ I found some new terms (particularly on the left side of the chart) a bit hard to remember; their descriptions seemed a bit technical so I had to go over and re-read them a few times (310)
Regulating one's self (0-1-0)		▪ keeping a slower pace, because i already have knowldege of the material (206)	
Remembering / Learning: General (3-0-5)	▪ Remembering some of the terms, and what they meant (103) ▪ Some of the topics were hard to remember (112) ▪ Remembering and recalling names or terms (121)		▪ Remembering the key words/terms' definitions... remembering most of the information, basically (301) ▪ Remembering all the facts (303) ▪ The parts I found challenging were what I can't remember. I'm not sure what the labels were but, I don't remember it (314) ▪ Trying to remember the facts (318) ▪ Just to remember what I was reading (320)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Remembering / Learning: Specific (5-7-8)	▪ What ever was mentioned in the upper left quadrant I completely am drawing a blank (104) ▪ Remembering the names of the methods used to process foods (105) ▪ There were a lot of subcategories with specific details in them that I could not remember (109) ▪ It was difficult to remember specific details (110) ▪ Some of the words were too large to remember (115)	▪ Remembering all the technical terms and all the details (201) ▪ Trying to study for the specific terms, some were quite confusing (207) ▪ remember points in each section (208) ▪ Remembering things from previous boxes, though having the visual map made this easier. (209) ▪ the many technical terms and definitions that had to be grasped (213) ▪ It was difficult to remember the more scientific facts which were presented at the begining when you have so much more knowledge aquired throughout the online learning experience (215) ▪ Remembering the long scientific words (220)	▪ Remembering the reasons/arguments supporting the advantages and disadvantages of the topic (301) ▪ Remembering the scientific definitions were difficult (302) ▪ The methods of developing novel foods (307) ▪ The concept of creating GM foods (308) ▪ the biology terms are hard to remember (309) ▪ remembering exact names, because they were mainly shown on the map the names of the particular thing i was studying were not retained as easily (312) ▪ difficult to remember the really long words on my first try, such as whichever one was directly at the top of the diagram - after the upper-left branch (315) ▪ Language used, many technical terms they used (321)

* Notes: Participants #118 and #211 reported not experiencing any challenges. Aside from text in brackets which were added to provide context, statements are verbatim. Numbers in brackets under the category topic indicate the number of statements per condition group in the order presented by the columns. Bracketed numbers beside statements are the participants' IDs.

APPENDIX U: RATIONALES FOR MAP UTILITY RATINGS

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Unfamiliarity with format (1-3-2)	▪ usually study out of online or book material that is set out in chapters and sections and therefor the map was somewhat overwhelming to look at (102)	▪ Web-diagrams seem to be very confusing…better if you placed the study materials in vertical location (203) ▪ It felt like it was all over the place (207) ▪ I may have looked at it more if it were at the bottom of the screen (220)	▪ I found the map kind of confusing (306) ▪ I found it a little confusing at first (315)
Required use of map for navigation (0-1-1)		▪ when we were supposed to look for the name and click to go on to the next stage, it took some time in looking for the term (207)	▪ (confusing) needing to look for my next step elsewhere (315)
Used primarily to navigate (0-0-3)			▪ but it was only navigation to me (303) ▪ I did not really examine the map once I selected the subject I read the paragraph and went on to the next one (314) ▪ I didn't pay much attention to it (318)
Control over navigation: Choice (positive) (2-0-0)	▪ I feel like I have more of a choice in what I want to know (106) ▪ It gave me the choice to study how I wanted to (112)		
Control over navigation: Choice (negative) (2-0-2)	▪ had find out where to start rather than numbered sequence (101) ▪ didn't know which way to go (102)		▪ the way in which I navigated the map did not seem to flow (304) ▪ unable to simply choose where to start (315)
Draws interest (1-1-1)	▪ (choice to pick topics) That is more interesting (106).	▪ I think without it, I would of switched off a while ago (210)	▪ I thought visually it was a good map (313)
Lack of appeal (2-3-0)	▪ didn't quite appeal to me (118) ▪ could have looked nicer too (118)	▪ It was a little too large (215) ▪ it was plain (217) ▪ not very appealing (217)	

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Provided a holistic view (2-3-3)	▪ The way the terms were organized made it…easier to grasp the concept as a whole (103) ▪ I feel like I can look at the whole structure of what I am learning at once (106)	▪ gives the whole picture of what I expect to learn in this topic (202) ▪ induces the studyer to connect the whole topic… because he could link it all, he has a much better understanding of it now (206) ▪ gave you a broad outline of what you were going to study in the beginning (213)	▪ The map functions as a general overview of the topic which is helpful before going into the specifics (307) ▪ it gives me the overall picture so I know what are the main topics and what are the subtopics (309) ▪ the…encapsulation of categories was helpful (315)
Chunked content (4-5-1)	▪ The way it was spatially oriented made it easier in my mind to decipher which topics could be categorized into which theme (109) ▪ it gave me a physical layout that I could fall back on when trying to remember the different areas (111) ▪ it helped to break the amount of information down into smaller manageable units (114) ▪ gave me an idea of what areas there were under the category (119)	▪ The map helps organize what I read into each category (202) ▪ it helped to bring up prompts in my mind to the more detailed material that was within each section (205) ▪ All of the concepts learned were placed under a heading (211) ▪ It helped keep my thoughts organized because it was done in branches and organized into 'folders' and 'subfolders' (214) ▪ It clearly mapped out each category (217)	▪ It was broken down into specific sections and those sections were broken down further into sections (302)
Indicated links & relationships (8-8-10)	▪ The map helped picturing the concepts and how they are related. sub categories or examples for any concept (105) ▪ The broader topic was always place in the middle of the web and each branching part represented a subtopic (109) ▪ I loved the use of the branching map because … one idea flow to the next (111) ▪ the map showed how topics were grouped together (112) ▪ it was a good way of organizing / giving	▪ It links concepts together (206) ▪ It helped me in remember relationships (208) ▪ When ideas would escape me from previous boxes, looking back at the map and the connections it has would help me to remember points that I had forgotten, and to make logical connections (209) ▪ clicking on a node of the map provided additional reinforcement, for example, at this point we will be studying Mutagenesis, then	▪ It was useful in a way, because it showed me how things were connected (301) ▪ I later realized that if I had paid more attention to the format and connections made between the topics I would have been able to remember more (303) ▪ The main topics branch out into subtopics provides me a useful conceptual map in organizing the ideas (305) ▪ This helps me to understand the relationship of producing GM foods, and its pros and cons (308) ▪ it helped me identify key terms and how they were related to eachother (310)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
	hierarchy / relations to the data (114) ▪ lines gave a sense of structure so I could tell what sorts of things were related to each other and how (116) ▪ It was useful to connect things and see the inter-connectedness of the topics (117) ▪ It was easy to see how the topics tied in with each other, and each topic was summed up in a concise way (120)	Objects, etc. (211) ▪ because the flow chart made the understanding and flow of information a little comprehensible (213) ▪ It showed the logical connections between the topics (216) ▪ it gave me a visual cue as to what the relationship was between concepts (218) ▪ It helps to visualize a relationship between topics (219)	▪ it does connect the ideas (312) ▪ It helped the tie in the relationships (313) ▪ the association...of categories was helpful (315) ▪ i get to keep track of how i can relate what i'm reading to a topic upstream (316) ▪ It was useful how the words were linked together after the provided information (319)
Related to difficulties with links (0-1-2)		▪ it was quite hard to find connections between the terms (207)	▪ I didn't really pay attention to the connections but rather finding the vocab so I could finish on time (306) ▪ there seemed to be too many branches which led to forgetfulness (312)
Aided visual learners (3-3-1)	▪ I'm a visual learner (107) ▪ I love learning spatially in a digram like this (106) ▪ It gave a visual picture, when i study i typically develop a visual picture of my notes in my head. It makes it easier to visualize where the information came from, it sometimes helps to remember what it said (110)	▪ useful as I consider myself a more visual learner (205) ▪ For visual learners, this is a great tool! (210) ▪ I learn better with visuals (221)	▪ I have a fairly good visual memory (317)
Did not fit with learning style / preference (1-1-5)	▪ isn't my desired method of studying so i have to try harder to maintain the information (104)	▪ I would much rather use an outline than a map (301)	▪ I do not like diagrams. I like learning from full sentences and any sort of graphical representation (304) ▪ (diagrams) usually does not help me, or even confuses me (304) ▪ It would have been more helpful to make my own (311) ▪ I don't like concept map to study about anything. This is just my preference (321) ▪ I do not normally take notes and organize what I am studying. I simply keep reading materials for exams

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
			many times to remember (321)
(Potentially) effective learning aid (2-4-5)	▪ The way the terms were organized made it easy to understand (103) ▪ Because it was already set up like this, I did not have to think about it too hard myself (109)	▪ The map is more organized, clear, and short. It help to memorize and understand the concept easier (201) ▪ It helped me organize the information in my head right from the beginning (204) ▪ I think the map was an ok study aid (217) ▪ something I could quickly jot down onto the paper before writing detailed descriptions, so I could be assured of not missing any of the major points (218)	▪ It would have been extreamly useful if I thought of it as part of the information, (but it was only navigation to me) (303) ▪ It also helped in brainstorming ideas and organizing where they fit I (310) ▪ It would have been harder without it (311) ▪ Visual cues are extremely helpful learning aides (next to narrative structures) ▪ didn't pay much attention to it) n retrospect I suppose if I had, it would have been useful (318)
Ineffective learning aid (2-2-1)	▪ did not help me memorize the information (120) ▪ It would have been more useful if we could go back to what we have read already (120)	▪ it did not help me to remember all the points in each subsection (208) ▪ Too much information to absorb in such short period (212)	▪ the headings were not very useful to me (304)
Provided direction (3-0-1)	▪ The information doesn't escape me as I read down the lines (106) ▪ It separates the topic into categories so that I know I should finish one section before going to the next one (108) ▪ I could read about one category at one time rather than randomly (112)		▪ Well....it pointed me in the direction I should go...and made it slightly easier to get info (320)
Showed one's location (3-0-0)	▪ it showed me what I had already read through (113) ▪ colors made it clear what I had gone through or not (116) ▪ it told me what I have not read yet (120)		

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Presentation (1-0-0)	▪ the pixels on the screenns did not tire out my eyes. I found it easy to learn the material, THe sixe of thetext matters too)106)	▪	▪

* Notes: Aside from text in brackets, which were added to provide context, statements are verbatim. Numbers in brackets under the category topic indicate the number of statements per condition group in the order presented by the columns. Bracketed numbers beside statements are the participants' IDs.

APPENDIX V: NAVIGATIONAL MAP'S STRENGTHS

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Chunked content (4-3-3)	▪ It seemed to be divided into seperate sections (102) ▪ broke down the information and the chunking made it easier to recollect (111) ▪ How there was categories with sub categories (112) ▪ abiilty to breakdown the topics into subgroups (114)	▪ organized into 'folders' and 'subfolders (214) ▪ it categorized the topics (217) ▪ easier to learn when there is a topic then subtopics and then further subtopics (302)	▪ brings together similar topics so the reader studies in sections the entire topic (314) ▪ Organization into primary, secondary and tertiary categories. Also, most titles had three tertiary catetories, making it easier to remember (317) ▪ well organized, breaking things down into more and more specific branches of the topic. (318)
Facilitated easier learning (3-2-1)	▪ Once I found and understood the map It became easy (101) ▪ easier to remember details (117) ▪ Visually it was easy to follow, very little filler text. It was very to the point (121)	▪ Understand the concept and easier to remember (it is easier to remember the images than text) (201) ▪ simplifies key concepts (221)	▪ easier to locate things (306)
Indicated links & relationships (5-10-10)	▪ It showed how terms were directly related (103) ▪ It was presented in a logical manner. Broader themes in the middle, with branching subtopics attached to it (109) ▪ to know which topics were related (115) ▪ see the relationships between topics and subtopics (117) ▪ how everything was brached in accordance to its relationship with one another (118)	▪ guidelines of where topics were speically located (203) ▪ The fact that they all drew back into GM Foods, and that it seemed closed off, and not linear (205) ▪ linkage between concepts made sense (206) ▪ see the relationships outlined before I began to read the finer details (208) ▪ links present between various ideas (209) ▪ clear graphical layout of the interconnectedness (211) ▪ it was easier for me to see clearly the relationship between the concepts (212) ▪ could see how topics were related and how they were subtopics (217) ▪ visual, outlined relationships (218) ▪ relationship between topics (219)	▪ showed links to the ideas, which helped me understand how closely the things are related (301) ▪ connections and order of topics (303) ▪ relationships between each topics and subtopics (305) ▪ clearly demonstrates the relationships between the topics (307) ▪ understand the relationships betwen different concepts (308) ▪ Once I remembered one concept, I was usually able to link it to a few more in the same branch (311) ▪ connecting the ideas (312) ▪ ability to see the association between topics and even how they linked to other topics (315) ▪ showing me how topics are related to eachoter (316) ▪ all had a relationship at

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
			some point (319)
Provided a holistic view (0-0-2)			▪ gives me the big picture (309) ▪ helps if you are a visual person....found sentences to be too detailed and tend not to remember the little things (313)
Provided organization (4-5-3)	▪ organization (105) ▪ organizing the topic- giving it headings and clarity (110) ▪ well organized (116) ▪ helped me organize essential information already (119)	▪ organizes the details into each category (202) ▪ Organization, more interesting visually, reiteration of information (204) ▪ helped to somewhat organize the ideas (207) ▪ The headings were laid out nicely (212) ▪ organized ideas (220)	▪ signalled a new topic, which helps with organizing the topics in my mind (304) ▪ helps me organizing thoughts (305) ▪ organize new information (310)
Served as a prompt (3-1-3)	▪ The map visualize where are the concepts, so I have a mental map on my head (108) ▪ The maps strengths were that it asked me after I read, how well I understood the material (113) ▪ I could bring to mind even after several minutes some of the topics I had studied simply from thinking of the structure (116)	▪ helped create a visual aid when trying to remember key concepts (215)	▪ worked as a memory aid when I was answering questions without the map actually in front of me (310) ▪ aided in recalling the concepts (311) ▪ easily to recall information from upstream and make relationship with what i have just read (316)
Showed one's location (2-3-1)	▪ you could trakc teh transference of knowledge (104) ▪ You could physically see where you had been and where you wanted to go (111)	▪ Makes it clear about how much more material is left for the studying process (207) ▪ Keeping track of where you've been and haven't been (214) ▪ showed the status of my progress and that was quite nicely done (216)	▪ The directions (320)
Had useful map format (1-2-1)	▪ The alignbmet of the boxes, the different colours, worked well (106)	▪ spider-web concept (210) ▪ flow chart system provide a visual/eidetic way to absorb information more readily (213)	▪ Looks neat and sometimes makes sense to me. Visually it could be memorable (321)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
**Text format (1-1-0)	▪ the variety of information, the organization of the texts (with only three sentences wriiten out in the same place with the same format) worked well (106) ▪ The explanations were very concise which made it easier to study (107)	▪ the topics and thier descriptions were short and too the point (213)	

* Notes: Participant #120 reported that the map did not have any strengths. Aside from text in brackets, which were added to provide context, statements are verbatim. Numbers in brackets under the category topic indicate the number of statements per condition group in the order presented by the columns. Bracketed numbers beside statements are the participants' IDs.
** Refers to the text, rather than the map itself.

APPENDIX W: NAVIGATIONAL MAP'S WEAKNESSES

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Control over navigation: Choice (5-1-5)	▪ Where to start (101 ▪ what topic to jump to afterward (101) ▪ Didn't know if there was a specific order I should be going in (112) ▪ I could only read one thing at a time (113) ▪ it didn't give me a definite place to start reading (119)	▪ Did not let me move around to the ones I wanted (204)	▪ It did not seem to have a logical flow (304) ▪ the next step was sometimes confusing...not expected (315) ▪ I may have wanted to read a different topic than the one I was lead to (315) ▪ how the order requires me to jump from topic to topic make it confusing to follow and recall (316) ▪ the order in which you were required to click (318)
Did not fit with learning style (0-1-2)		▪ seemed like there were many topics that were required and didn't give me any motivation on learning outcomes (217)	▪ it wouldn't be helpful if you weren't a visual person (313) ▪ People usually read from left to right, but the map...made it a bit for challenging (317).
Restricted navigation & study strategy use: Review (5-5-0)	▪ Not being able to re-read the definitions of terms after choosing another term (103) ▪ i couldnt' go back to review the information (110) ▪ could not return to previously viewed topics (117) ▪ wouldn't let me go back (120) ▪ Not being able to go back (121)	▪ I can't go back (208) ▪ Not being able to go back and look at things...to make connections (209) ▪ failure to go back and re-read (213) ▪ Not being able to go back and re-read (214) ▪ not being able to revisit topics (216)	
Unable to use own study strategies (0-0-1)			▪ it was already made for me (311)

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Difficult to get overall picture (1-1-3)	▪ a bit difficult to get an overall picture of all the information together (110)	▪ it would help to outline the key points easier (208)	▪ showed the topics/subtopics with no supporting details (unless i clicked on the topic), compared to outlines wherein you know what is contained in a topic/subtopic (301) ▪ As well, the physical structure of it (central with branches) was harder than I imagine headers and points would have been (311) ▪ It was not easy to understand it all at once (319)
Not distinguishable enough (2-0-1)	▪ main headings were not distinguished from the subheadings (102) ▪ no colorization so gradually all the breanches began to meld (104)		▪ different coloured boxes might help me organize event further (310)
Lacked details (simplistic) (0-4-4)		▪ May not contain a lot of detail information (201) ▪ didn't have extra brief points about the individual concepts (212) ▪ the simplicity of the structure (217) ▪ sometimes over simplified (220)	▪ only showed the topics/subtopics with no supporting details (unless i clicked on the topic) (301) ▪ It was very basic (310) ▪ In the map, even though the topics were connected, it wasn't specific as to how it was connected (313) ▪ There were not much information given (319)
Too many chunks / points (complicated) (2-2-4)	▪ it was divided up in such small amounts, i had to intentionally relate the topics in my head (110) ▪ many topics, and each topic had a variety of different facts...difficult to retain everything (116)	▪ remember the sub-sub categories was very difficult (215) ▪ too many points to consider at one time (221)	▪ can be confusing if it's too complex (305) ▪ It's kind of complicated (308) ▪ has too many arrows; it should be broken down into 2 maps (309) ▪ too many titles, didn't retain much information from the map (312)
Concept location issues (1-2-1)	▪ i remember the positioning of an item, but not the item itself (114)	▪ could have been better linkage between certain concepts. The two concepts without other branches could have been added into a different branch (206)	▪ a few randomly thrown in topics (like biotechnology) that didn't seem to be linked to anything other than the main topic; it wasn't able to be broken

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
		▪ at some points I would disagree with how some of the information was categorized (211)	down further (302)
Terminology used (1-2-3)	▪ some terminology that I did not understand (107)	▪ title of each brach makes it difficult to remember the points, or to look back and remember (207) ▪ a few technical terms and one spot where I'm not sure what the specific term used was because it could have been several different things - mutagenesis, selective breeding and hybridization came off of this unknown cell (218)	▪ headings should be more useful and easier to understand (304) ▪ titles did not indicate completely what the paragraph intended (314) ▪ Also, the simple titles were easier to remembers than the ones that used sophisticated scientific headings.(317)
Aesthetics (1-3-1)	▪ didn't look nice (118)	▪ it was all over the place (203) ▪ The colours (210) ▪ didn't like the format (217)	▪ Small print and font (320)
Distracting (0-1-2)		▪ diagram is too big and attrative that makes reader can't focus on content at the bottom (219)	▪ a lot going on in the page so I kind of found myself distracted by it (306) ▪ distracts me from thinking deeply. Just looking at the maps over and over without elaborating or thinking of it (321)
Used as the means for navigating (0-0-1)			▪ It was made into the navigation bar (303)
Environment (1-0-0)	▪ after a period of time,your eyes get soar from looking at the computer (106)		
Had to rate one's learning (2-0-0)	▪ keep forgetting to rate the materials (108) ▪ having to click on the drop down menu and select an option (111)		
**Text (1-0-0)	▪ text was not in bullets or point form (115)		

* Notes: Participants #105, #106, #109, #205 and #307 reported that the map did not have any weaknesses. #202 did not respond (typed a "-"). Aside from text in brackets, which were added to provide context, statements are verbatim. Numbers in brackets under the category topic indicate the number of statements per condition group in the order presented by the columns. Bracketed numbers beside statements are the participants' IDs.
** Refers to the text, rather than the map itself.

APPENDIX X: SUGGESTIONS FOR IMPROVING THE MAP

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
Provide choice for navigation (0-0-2)			▪ given multiple options on where to read next at times (315) ▪ freedom of choosing their topic (316)
Improve navigational directions (2-1-2)	▪ using arrows or numbers to guide throught the topics (101) ▪ more of a top down or left to right approach, i didn't know where to start and where things went (114)	better if the link is in the text instead of clicking back to the map (207)	▪ colour code it to brighter colours so that it is more visible to see which one's you have already done and which are left (306) ▪ Maybe some mode of highlighting the next step (315)
Allow for review (5-4-0)	▪ ability to move back and forth (101) ▪ to be able to go back (102) ▪ allow the user to go back (113) ▪ lets me go back (120) ▪ Being allowed to go back (121)	▪ go back to review (208) ▪ able to reclick (209) ▪ to go back (214) ▪ allow the user to return (216)	
Further distinguish content (7-3-7)	▪ Distinguishing the headings from the sub headings (102) ▪ add a color specific to each of the four main branches (104) ▪ highlighting the center of the map (107) ▪ Make the font larger for the broader themes to make them stand out more (109) ▪ Possibly number the subtopics so that whoever is studying the material can quantify how many key points are associated with each topic (109) ▪ one or two size differences in the text/box so that a sense of hierarchy could be given, and the branches would feel like there	▪ used different colors to inditcate that this was the topic (203) ▪ change fonts and or colors of the boxes to relate a certain color, etc with a certain idea (204) ▪ Colour coding (220)	▪ adding a little colour coordinating would help. It seems to work for me with highlighters and such)302) ▪ And not making all the boxes or texts the same; differentiating the topics a bit more. So perhaps the main theme (novel foods) could have been bold in a box, whereas a subtopic like GM could have been italicized and in a circle (302) ▪ size fonts or colors of the topics can be altered and grouped to provides better understanding (305) ▪ break it down a bit and use different colors to differentiate main topics and subtopics (309) ▪ Highlight boxes, bold text (310) ▪ the map should be bolder,

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
	were different levels to work through (not just a bunch of boxes all together) (116) ▪ Emphasing the main idea/topic in text boldness or color (119)		colour coded and important parts highlighted (314) ▪ add colour for different levels (320)
Provide more associated content (5-7-6)	▪ show the definitions in or beside the boxes (103) ▪ adding additional leyers of information for studying aids (106) ▪ Some links to find more information would be helpful in the diagram (106) ▪ follow it with a summarizing paragraph (110) ▪ place a corresponding picture into each box for viewers to have another cue that they can refer to (111)	▪ summerize the information and added into the map images to help understand the concepts (201) ▪ incorporate tool-tips so that the user can preview a node before selecting it, especially if the nodes are heavier on info then three sentences (211) ▪ Have brief points under each concepts, so one wouldn't have to re read the paragraphs to get what exactly each heading was talking about (212) ▪ Make the category title appear at the top of every text page it refers to (215) ▪ more helpful if it had more web links to interesting facts (217) ▪ maybe some more examples to tie the topics together (217) ▪ label the connections between cells with verbs so the relationship is immediatly apparent without having to read the details of each cell (218)	▪ Add supporting details that show what a topic is about - not just a general term (301) ▪ Add diagrams/pictures beside or below them (details) (301) ▪ in the lines, you can put a few words to explain the relationship (313) ▪ Perhaps a glossary of the more confused terms (315) ▪ Maybe a paragraph of information telling you about how the map is related to each word and some additional information about the map (319) ▪ I would write something next to each map. - Explanation or some little notes (321)
Reconsider links (2-2-0)	▪ The categories with no sub categories (there was one branch each from the middle but didn't continue) seemed out of place (112) ▪ Perhaps less branches (116)	▪ better linkage between certain concepts. The two concepts without other branches could have been added into a different branch (206) ▪ Simplify the map even more by grouping key points in the same category, and including pictures (221)	
Reconsider terminology (0-1-3)		▪ use simplier names for the branches (207)	▪ Do not use scientific terms which most people are not familiar with as topic headings (304) ▪ The titles should indicate

Category	Free (group 1)	Clockwise (group 2)	Yoked (group 3)
			better the topic being studied (314) ▪ Eliminate use to overly scientific language in headings (317)
Make more flexible / interactive (0-1-1)		▪ make it collapsible when there are larger texts or diagrams so the user can get the map out of the way if he wants to and just focus on the text (211)	▪ Allow me to arrange the branches or choose a different format (headers with notes, e.g.) for the same arrangement (311)
Change the format (1-2-6)	▪ The map might not need to actually look like a web. Maybe you could organize it into columns so that at the top of each column, there is the broad theme's title and underneath it there are the subcategories (109)	▪ I think it is better to draw the map by hand than showed on the computer (201) ▪ better if guidelines were in vertical line (202)	▪ To be made separate from the buttons (303) ▪ Maybe categorize the map into a 'brainstorm' map format. For example: 'What is genetic modification?', 'Critiques of GM', and 'Benefits of GM' (304) ▪ Break it down into serveral relationship maps. (308) ▪ have a hierachy structure (310) ▪ more linear, because that is the way we have become accustomed to with textbooks (312) ▪ Could also use a vertical orientation to the chart to relationships are more direct and clear, visually, i.e, arrows leading down from biotechnology, to Novel Foods, to GM foods etc. (317)
Increase interest (1-2-1)	▪ Adding sounds or images as you press certain parts of the diagram would be really fun (106)	▪ use of differing medias - audio would be great! (210) ▪ Images would also help for the interest factor (217)	▪ have some (additional) interesting topics so readers are interested in reading more (319)
Improve aesthetics (3-1-1)	▪ some people may want to make the text bigger (106) ▪ It is very green and gray (108) ▪ make it look nicer, so that there is a better layout (118)	▪ A smaller diagram perhaps (219)	▪ Bigger font and print (320)
**Simplify text	▪ bullets for the text (115)		

* Notes: Participants #105, #117, #205, #307, #318 reported having no suggestions, #213 did not answer the question in a manner that provided data for this table and #202 did not respond (typed a "-"). Aside from text in brackets, which were added to provide context, statements are verbatim. Numbers in brackets under the category topic indicate the number of statements per condition group in the order presented by the columns. Bracketed numbers beside statements are the participants' IDs.

Appendix Y: Sample Learner Profile with Eye movement Data

Nikki

A 19-year old Business student with 41 credit hours, GPA of 2.74 and low prior knowledge score of 1.0, Nikki started using a computer 12 years ago. She reported learning online versus print to be about the same since she has taken eight courses with online materials. Nikki scored 103 out of 170 for knowledge of cognition and 188 out of 350 for regulation of cognition. Of particular interest is a low score for monitoring (27/70) and its potential effect on her learning.

Studying Experience

Nikki studied for 7 minutes and 5 seconds. Not making use 30% of the available time may suggest some challenges with pacing and initial planning. *Figure G* shows the order of topic pages Nikki selected. Nikki (and Nora) started in the centre hub and then selected the two single node branches. From there, topic selection appeared to be based on a progression toward the left side of the screen using a clockwise pattern. Proximity rather the links between a topic and subtopics seemed to drive navigation on the left side of the map, whereas this changed on the right side when she was almost done with studying. Then, a topic was viewed before selecting its subtopic (e.g. *Canadian Regulation* → Marketplace Implications). Perhaps after some time, Nikki noted the topic-subtopic relationship and adapted her navigational behaviour as a result.

Figure G: Nikki's selected path (and followed by Nora).

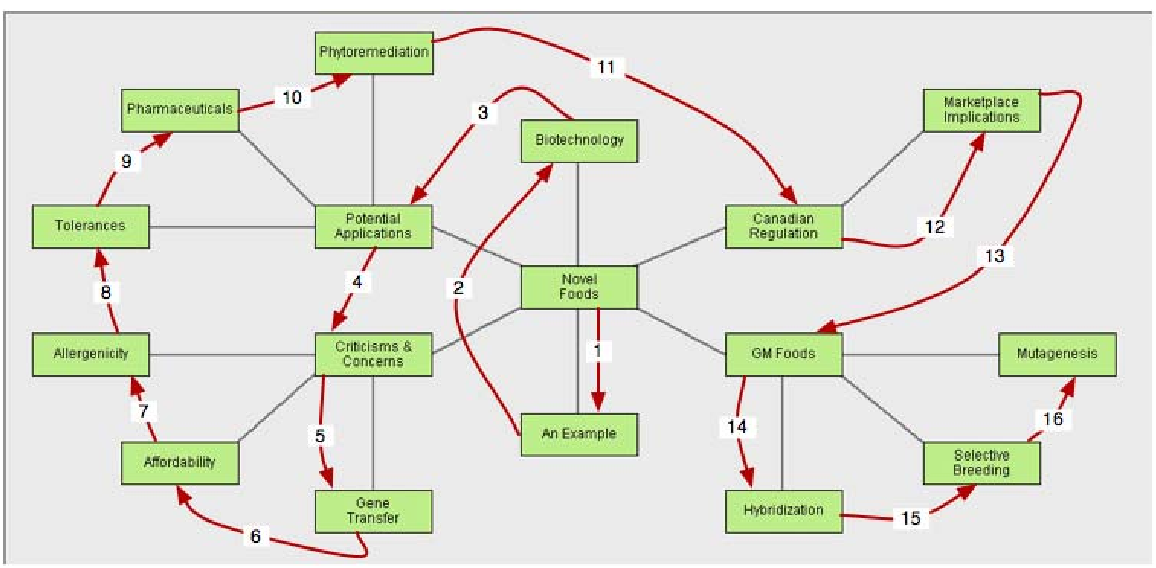


Table A illustrates Nikki's scanpath between the map and text LookZones, the number of topic LookZones she studied and the number of topic LookZones she reviewed for that web page. Topic LookZones are located within the map LookZone. The pages are listed in the order Nikki viewed them. Twelve of the seventeen topic LookZones were studied on the first page, suggesting that Nikki first performed a partial overview of the material to be studied, engaging in some planning. She carried out some review by observing half of the topics on the map before ending the study session. For both these pages, Nikki reviewed several topics nodes by observing them initially and then re-examining them while still on the same webpage. For all study pages, the map appeared to serve as an initial starting point prior to reading the text. The topics on the map were not frequently viewed, let alone reviewed during the study session as seen in the far right column of the table. Nikki alternated between the map and text several times per web page. The frequency decreased about two-thirds into the study session and then increased toward the end of the study session.

Table A: Nikki's scanpath: initial and reviewed topic LookZones.

Page	Selected Topic Web Page	Scanpath between Map and Text LookZones: Time in Seconds*	# Unique Topic LZs Studied	# Topic LZs Reviewed
0	Start	Map (1.0s) → Text (4.0s) → Map (3.0s) → Text (.39s) → Map (4s) → Text (8.0s) → Map (9.3s) → Text (16.4s) → Map (2.8s)	12	10
1	Novel Foods	Map (2.3s) → Text (4.5s) → Map (0.2s) → Text (11.7s) → Map (7.2s) → Text (5.9s) → Map (0.1s) → Text (0.3s) → Map (1.2s)	5	3
2	*An Example*	Map (1.2s) → Text (15.3s) → Map (1.3s) → Text (3.5s) → Map (2.3s)	5	3
3	*Biotechnology*	Map (2.8s) → Text (3.8s) → Map (1.1s) → Text (19.3s) → Map (1.7s)	6	6
4	*Potential Applications*	Map (0.8s) → Text (18.8s) → Map (1.9s) → Text (4.6s) → Map (0.1s) → Text (1.4s) → Map (2.6s)	2	2
5	*Criticisms & Concerns*	Map (2.7s) → Text (0.6s) → Map (0.7s) → Text (12.3s) → Map (0.9s) → Text (.9s) → Map (3.1s) →Text (1.9s) → Map (0.5s) → Text (0.4s) → Map (1.5s)	6	2
6	Gene Transfer	Map (0.5s) → Text (2.1s) → Map (0.2s) → Text (0.3s) → Map (1.0s) → Text (14.7s) → Map (1.6s)	3	2
7	Affordability	Map (0.2s) → Text (13.8s) → Map (0.5s) → Text (0.3s) → Map (0.8s)	2	1
8	Allergenicity	Map (0.4s) → Text (20.5s) → Map (0.3s) → Text (0.5s) → Map (0.6s) → Text (2.2s) → Map (2.0s)	4	1
9	Tolerances	Map (0.6s) → Text (2.36s) → Map (0.3s) → Text (20.6s) → Map (2.2s)	6	4
10	Pharmaceuticals	Map (0.3s) → Text (17.1s) → Map (1.4s) → Text (2.1s) → Map (1.5s)	3	3
11	Phytoremediation	Map (0.5s) → Text (1.2s) → Map (1.3s) → Text (15.3s) → Map (2.2s) → Text (3.1s) → Map (0.6s) → Text (0.2s) → Map (1.5s)	7	6
12	*Canadian Regulation*	Map (1.2s) → Text (16.3s) → Map (0.9s) → Text (2.2s) → Map (2.2s)	4	3

Page	Selected Topic Web Page	Scanpath between Map and Text LookZones: Time in Seconds*	# Unique Topic LZs Studied	# Topic LZs Reviewed
13	Marketplace Implications	Map (0.4s) → Text (21.1s) → Map (2.1s)	3	2
14	*GM Foods*	Map (0.3s) → Text (14.8s) → Map (1.4s)	2	2
15	Hybridization	Map (0.3s) → Text (16.6s) → Map (0.5s) → Text (0.5s) → Map (2.0s) → Text (2.2s) → Map (1.7s)	5	2
16	Selective Breeding	Map (1.7s) → Text (3.6s) → Map (0.2s) → Text (3.1s) → Map (3.3s) → Text (1.7s) → Map (0.6s) → Text (4.1s) → Map (0.8s) → Text (0.4s) → Map (0.1s) → Text (0.2s) → Map (1.1s)	9	4
17	Mutagenesis	Map (0.3s) → Text (4.28s) → Map (0.2s) → Text (3.5s) → Map (0.2s) → Text (4.0s) → Map (11.0s) → Text (2.9s)	14	9

Table B identifies the total time Nikki spent on each webpage, the total amount of time she was fixated, and her rating on how her learning was progressing. The top row indicates the page order. The top three rows of data indicate that Nikki generally spent less time on LookZones on the latter pages, compared to the beginning, was fixated most of the time and rated her learning as "good" across the entire study period. The next section (grey) in the table shows the number of times Nikki alternated between the map and text LookZones, which suggests monitoring and debugging between the textual and visual content.

The first column lists all of the LookZones starting from the centre and then moving clock-wise. "Novel foods" is bolded to show that it is the central topic, followed by topics and subtopics indicated with italics and plain text respectively. This helps to provide a visual depiction of the chunks of related LookZones. For example, for the first three pages, Nikki spent most of her time on the map looking at the centre LookZones since there is data for those LookZones, with very little time to the ones on the left (gene transfer, potential applications) and no time at all on the LookZones to the right of the map (e.g. nothing under Marketplace Implications or GM Foods).

To read this part of the table in more detail: Each numbered column outlines data for that particular study page. The top number in the cell indicates the number of observations Nikki observed a particular LookZone, while the bottom number indicates the percentage of time she observed that LookZone for that page (unrelated to the frequency of observations). The "T" beside the number of observations identifies the topic being studied while the "N" indicates that the next topic to be studied. The reason why I flagged this is because this LookZone must be observed at least once in order to click on the topic and move to the next page, so any number higher than one suggests a further observation of that topic on the map. An example, looking at the page 1 column: Novel foods was the topic being studied since it has a 'T". Nikki viewed this LookZone nine times and spent 10.3% of her time studying the page, in this LookZone. "An Example" was the topic she studied next. She viewed this LookZone five times and this took 8.2% of her study time on the Novel Foods page.

Interestingly, over the study period, patterns in LookZone viewing emerge. The main concept, novel foods, was one of the most viewed nodes. The two single branched sub-topics were also viewed more commonly. We see that the two-node branch was ignored after the start page and viewed only for navigation on page 11 and then was viewed when it was the topic being studied (on page 12). Similarly, the GM Foods branch, which is also on the right side of the map, was not viewed until it became a general area for navigation and the topic to be studied. Topics on the left side of the map were viewed more frequently over the study period with concentrations also occurring when the area became the focus for navigation or the topic to be studied.

To summarize Nikki's map use, it appears that Nikki did use the map for some initial planning prior to studying, definitely used it for navigation by looking at the topics, deciding on where to go next and clicking on the node. Review behaviour may be suggested by the alternating path between the map and text (in grey) and the number of observations per node above “1”. For example, if we look under the “Start” page, we see that Nikki observed the map LookZone five times and the text LookZone four times. She had to look at each once in order to read the instructions (in the next) for navigating and then the map to select the next topic. Given that she viewed each more than once, we can surmise that she engaged in review behaviour.

Table B: Nikki's number of observations and percent of time spent on individual LookZones per page.

	Page Order																	
	Start	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Total time on page (sec.)	46.6	31.2	23.6	28.7	32.0	24.9	22.2	17.11	29.0	28.8	22.5	26.6	23.7	23.7	16.8	24.1	21.3	26.9
% time fixated	82.0	92.1	90.0	92.3	86.6	88.8	75.3	81.2	79.6	85.8	83.4	82.2	86.4	83.0	90.0	90.7	88.7	80.4
Learning Rating*	N/A	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
Map	5	5	3	3	4	6	4	3	4	3	3	5	3	2	2	4	7	4
	30.2	27.3	19.7	18.9	16.6	32.2	10.5	9.6	11.2	11.4	10.9	19.0	18.7	10.6	9.9	18.9	36.6	43.4
Text	4	4	2	2	3	5	3	2	3	2	2	4	2	1	1	3	6	4
	61.7	71.7	79.8	80.6	77.5	65.1	76.5	82.7	80.2	86.2	85.2	74.3	78.7	81.5	88.4	80.2	61.8	54.7
Novel Foods**	7	9[T]	5	5	0	1	0	0	0	0	0	3	1	0	0	1	1	3
	6.2	10.3	4.4	4.3		1.4						2.1	1.7			3.0	0.9	1.5
An Example	4	5[N]	5[T]	2	0	1	0	0	0	0	0	4	0	0	0	3	1	0
	0.7	8.2	3.2	0.7		0.3						0.4				1.1	1.4	
Biotechnology	4	3	3[N]	4[T]	0	0	0	0	0	0	0	2	0	0	0	0	2	1
	0.2	5.7	8.0	4.7								1.1					2.4	2.1
Canadian Reg.	1	0	0	0	0	0	0	0	0	0	0	1[N]	4[T]	0	0	0	0	0
	1.4											4.2	5.9					
Marketplace Implications	2	0	0	0	0	0	0	0	0	0	0	0	2[N]	2[T]	0	0	0	0
	1.5												7.7	2.8				
GM Foods	2	0	0	0	0	0	0	0	0	1	0	0	3	2[N]	2[T]	1	3	1
	2.2									1.2			1.3	5.2	4.3	1.6	4.9	1.3
Mutagenesis	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1[N]	3[T]
	1.1													1.5			5.0	5.6
Selective Breeding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1[N]	6[T]	4
																4.0	6.5	1.7

	Page Order																	
	Start	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Hybridization	4 0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	2[N] 5.4	5[T] 8.2	5 3.2	4 2.1
Criticisms & Concerns	2 1.0	0	0	3 2.3	5[N] 6.2	6[T] 6.8	1 0.8	0	0	14 1.0	0	4 2.3	0	0	0	0	1 1.5	2 1.8
Gene Transfer	0	1 0.5	1 1.6	2 0.5	0	7[N] 19.3	5[T] 4.2	0	0	2 0.7	2 0.6	4 0.7	0	0	0	0	0	1 1.4
Affordability	0	0	0	0	0	1 1.3	1[N] 5.0	3[T] 5.19	4 1.2	0	0	0	0	0	0	0	0	2 2.4
Allergenicity	0	0	0	0	0	0	0	1[N] 3.8	3[T] 4.7	1 0.5	0	0	0	0	0	0	0	4 6.4
Potential Applications	5 2.6	1 0.5	1 0.7	4[N] 5.2	4[T] 8.2	1 1.4	0	0	1 0.9	0	0	0	0	0	0	0	1 2.5	2 3.0
Tolerances	0	0	0	0	0	0	0	0	2[N] 2.6	2[T] 1.6	0	0	0	0	0	0	0	2 2.1
Pharmaceuticals	2 1.2	0	0	0	0	0	0	0	0	5[N] 3.2	3[T] 2.8	0	0	0	0	0	0	1 2.2
Phytoremediation	6 2.8	0	0	0	0	0	0	0	0	0	4[N] 5.5	5[T] 5.6	0	0	0	0	0	1 1.7

[T] Page's topic
[N] Topic navigated to after studying the current page
* VG = Very Good; G = Good; A = Acceptable; P = Poor; VP = Very Poor
** Bold = central topic; Italics = subtopic from central topic; Plain = subtopic branched from italicized preceding topic. Top number = # of times observed; Bottom number = % of time studying the page spent in the LookZone.

Studying & Achievement

Nikki's scores on the recall and application measures were 0.5 and 3, for a total score of 3.5, which was the third lowest in the study. For the recall measure, she drew a diagram, but incorrectly identified components and relationships. Nikki received 0.25 for a detail in the text from "An Example" and 0.25 for "Hybridization", a term visible in the map and text for that topic. While studying the pages for each of these topics, Nikki observed the topic's node on the map five times and spent 80% of her time on the page, studying the associated text.

Nikki scored a point for three ideas in her response to the application question. The first related to the text under "Canadian Regulation", the second was a new idea related to environmental considerations (loosely tied to "Criticisms & Concerns"), and the third, for identifying an aspect of "Novel Foods". Nikki evidently derived her responses from the text content, rather than the concepts on the map and their relationships.

Reflections

When asked about her studying experience, Nikki noted that it consisted, "mostly of reading". Depending on how literally one takes this, this could suggest little use of the map where a person would "look" or "study" it and little engagement. Nikki evaluated her actions as evidenced in her comment, "I read everything over once, but should have read it over twice". Nikki rated her motivation with "3" on a 0 to 5-point scale, communicating a moderate level of motivation and revealed disinterest in the topic with her rating of "0". Nikki reported that the layout was easy to understand, but reading on the monitor was challenging.

In terms of the map, Nikki declared that it was moderately useful with a rating of 3 on a 0 to 5 point scale and explained that it was useful because it identified where she had already visited. Nikki reported that the map helped her to consider how well she understood the material after reading (monitoring), but prevented her from reading more than one topic at a time. Nikki recommended allowing students to go back to previously studied topic, which suggests that she may have been aware that the map could better enable monitoring and debugging.

Implications

It appears that several factors may have affected Nikki's performance in the study. Subscale scores on the MAI generally hovered at the mid-point of the scale, except for her low monitoring score. Her ability to self-regulated may have been reflected in her less than optimal use of the available time where she completed studying with 30% of the time remaining, Navigating by proximity rather than through the links between terms, it is not clear whether Nikki recognized the links between topics and chose not to access them. Given that she did not refer to relationships between topics or the links in her open-ended responses, suggests that she was not aware of the links or used them. Monitoring occurred more frequently at the start and end of the study period as Nikki alternated between the map and text LookZones more frequently. For many pages, it was evident that she was only using the map to find the next topic to select. For most of session Nikki only observed the immediate topic on the map, rarely some of the topics around it, and review of the topics was infrequent. Given the time she spent on the other topics in the map, it appears that she glanced over these for navigational purposes rather than for study.

Nikki's very limited map use was evident in her test question responses, which were derived from the text. Although she indicated that her learning was "good" throughout the entire study period, this is suspect not only because the rating did not vary at all, but also because of Nikki's very low scores on both achievement measures. She recalled almost nothing. It is unclear to what extent Nikki's poor performance was due to a weakness or disinterest to self-regulate and due to external factors. A moderate level of reported motivation and no interest at all in the subject confirms a disinterest, yet her MAI scores, consistent rating of "good" and report that the map helped her to consider how well she understood the material suggests that she may have had trouble with self-regulating (monitoring and evaluating in particular). An external factor that impacted Nikki was the inability to review the text, as she noted in her self-report. In sum, it appears that Nikki's self-regulation abilities, personal constructs (interest, motivation), and the study's set-up (map and subject matter) influenced her performance and in her case, learner control over topic selection may have been detrimental given these factors.