Integrating link maps into multimedia: An investigation

Nigel Choon Hao Kuan
SUPER
School of Physics
University of Sydney
Abstract

Novices often see physics as a vast expanse of complicated and disconnected concepts and theorems. This is problematic for both the students and the physics community. To address the problem, this project has synthesised a number of research areas (link maps, concept maps, cognitive load theory and multimedia learning) into a unique teaching and learning tool for high school physics education. In doing so, ‘link map’ tools were developed in computer and video-based multimedia. Investigation of the effects of such tools on students was carried out through a number of Sydney high schools. Both tools had a positive effect on student attitudes and beliefs about physics, shifting them to more ‘expert’ views. The two tools also increased student achievement, as well as the complexity of student knowledge structures, with no statistically significant difference between the effects of the computer and video tools. Importantly, student and teacher views about the link map tools were uniformly positive, demonstrating the success of the synthesis of research areas into a pedagogically viable tool for high school physics contexts.
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Statement of Student Contribution

The research question was framed by Nigel Kuan. All research, development and analysis was undertaken by Nigel Kuan, with advice from A/ Prof. Manjula Sharma, Dr Derek Muller and Dr Christine Lindstrøm. The Flash computer tool was developed by Nigel Kuan but programmed by Mr. Ben Butler. Likewise, the video tool was developed (and ‘acted’) by Nigel Kuan, with camera and editing help from Dr. Derek Muller. Identification and selection of the evaluative framework and tools was by Nigel Kuan. As such, all cases of ‘we’ within this thesis essentially mean ‘I’. It is also worth noting that throughout this thesis ‘students’ is synonymous to ‘research participants’.

I certify that this report contains work carried out by myself except where otherwise acknowledged.

Signed

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Chapter 1

Introduction

Physics education plays a vital and important role for everyone. From the quality of the astrophysics professor’s new PhD student, to an understanding of the inaccurate professions of ‘ion-healing’ charlatans — physics education matters. This is where physics education research comes in, investigating the nooks and crannies of how physics knowledge and learning come together and, importantly, how to improve it. The impetus is definitely there. At a local level, there is a large and continual under-supply of scientists and engineers in Australia (Australian Government Department of Education and Training, 2006; The Australian Academy of Technological Sciences and Engineering, 2006). At a more profound level, the evolution of science and technology is having an ever greater impact on our human civilisation. Considering this, the great science educator, Carl Sagan (1980), identified a problem;

We’ve arranged a civilisation in which the most crucial elements profoundly depend on science and technology. We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology. — Cosmos, 1980

The somewhat scattered physics education research groups thus have an important role to play in addressing this problem; whether at a primary school, high school, or university level. The research contained within this thesis focuses on the teaching and learning of physics at a high school level. Traditionally, the examination of tertiary physics education has been the research staple of various university physics education research groups. However, research into physics education at the high school level has its own unique and profound benefits. Indeed it allows an understanding of both the prior knowledge and experiences of physics undergraduates as well as, to a rough approximation, the physics understanding of the general public.

It is within this context that the research in this thesis is framed. This research addresses the question of how to improve the teaching and learning of physics for high school students, through an investigation into the novel synthesis of various research areas within the physics education landscape. Current, promising research on ‘concept maps’ and ‘link maps’ was integrated into the solid research base of multimedia design — towards development of new teaching and learning tools. These video and computer tools, were used to investigate their effects on student attitudes and beliefs about physics, student achievement, and teacher views. In doing so, the study aimed to propose and evaluate a concrete, research-based methodology on the implementation of the link/concept map framework into multimedia-based physics instruction.

It is useful to provide a very brief general outline of this thesis. Chapter 2 discusses the research literature relevant to this research project. The development of the multimedia tools and the evaluative framework used to assess them are discussed in Chapters 3 and 4 respectively. Details of the data collection are outlined in Chapter 5, with results and analysis following in Chapter 6. Chapter 7 will then discuss the important findings of the study, with Chapter 8 providing some concluding remarks.
Chapter 2

A review of the literature

2.1 Constructivism

When addressing teaching and learning, one has to address the epistemological question of “how do we come to know what we know?” Constructivism is an answer to this question, one which has established itself as the overarching framework of how learning is viewed within the modern education research community. Although constructivism has many flavours (McInerney & McInerney, 2006), one can sum up the core principle simply — “knowledge is constructed in the mind of the learner” (Bodner, 1986). This construction and organisation of knowledge builds cognitive structures called schemata1. Schemata are essentially the structures which compose a person’s beliefs, understandings and explanations. Schemata represent one’s necessarily subjective knowledge of the world (Saunders, 1992).

The significance of constructivism in the modern context is that it has shifted the practice of teaching and learning (Prawat, 1992). Modern constructivism emphasises that learning is student-centred, shifting focus away from more transmissive teacher-centred pedagogies, emphasising the processes of knowledge accretion and assimilation within the learner (Windschitl, 2002). An ‘extreme’ but nonetheless useful statement of the constructivist view is: “You cannot teach anybody anything. All you can do as a teacher is to make it easier for your students to learn” (Redish, 1994). It is this consideration of the factors that surround the learning in students which is characteristic of constructivism. In the modern educational research paradigm, constructivism is the framework in which everything rests, and the discussions below about cognitive load theory and educational multimedia research are no different (considered under the framework of ‘information-processing constructivism’ (McInerney & McInerney, 2006)).

2.2 Concept maps

Since the formulation of concept maps by Joseph Novak in the 1970s (Novak & Cañas, 2006), concept maps have made a significant impact on educational discourse, and today pervade most levels of education in various incarnations. Concept maps are a representation of concepts and their interrelationships, intended to be representative of the knowledge structure that humans store in their minds (Jonassen, Beissner & Yacci, 1993). Indeed, concept maps are essentially graphical tools that serve to organise and represent knowledge.

Regarding the structure of concept maps, ‘concepts’ are usually enclosed in some sort of frame (as a whole called a ‘node’). The relationships between various concepts are indicated by connecting lines linking concepts (called ‘links’). Often, words around the line, called ‘linking words’ or ‘linking phrases’, specify the relationship between the two concepts (Novak & Cañas, 2006). An example of the general structure of concept maps is shown in Figure 2.1.

Concept maps have their foundation in David Ausubel’s psychology and learning theory (Ausubel, 1963, 1968; Ausubel, Novak & Hanesian, 1978). Essentially constructivist, Ausubel’s cognitive psychology rests on the fundamental principle that learning takes place through the assimilation of new knowledge into the existing knowledge frameworks held by the learner. This concept of assimilation

1Note that ‘schemata’ is the plural to the singular ‘schema’.
is a cornerstone of constructivism, coined by the key constructivism pioneer, Jean Piaget (1953). Considering this notion of assimilation leads to an important conclusion — students’ prior knowledge have significant influence on meaningful learning. Ausubel distinguishes between ‘meaningful’ learning from ‘rote’ learning, suggesting three conditions which concept maps rely on to promote the former (Novak & Cañas, 2006):

1. The material to be learned must be conceptually clear, and relate to the learner’s prior knowledge.
2. The learner must possess relevant prior knowledge.
3. The learner must choose to learn meaningfully.

The cognitive process of concept mapping has been denoted by McAleese (1994) as ‘auto-monitoring’. Concept mapping requires of the learner constant explication and reflection; a constant re-constructing and re-presenting of what is known. As such, the technique involved in concept mapping may be novel to many learners. Therefore, in any learning setting, the process needs to be explained thoroughly using familiar concepts, to prime students before they are able to map their own ideas (Taber, 1994).

Significant research has been undertaken investigating the efficacy of concept maps, demonstrating their promotion of meaningful learning in a range of educational contexts (Hattie, 2009; Novak, 1998). The versatility of concept maps has been shown, in its effectiveness as a teaching/instructional tool (Horton, McConney, Gallo, Woods, Senn & Hamelin, 1993), learning tool, and in (more formative) assessment contexts (Tsai, Lin & Yuan, 2001). Concept mapping has also proven to be a useful tool for students to examine their prior knowledge, helping learners to identify what they do not know (Gurlitt & Renkl, 2008). In science education contexts, concept maps have been shown to have positive effects on student learning (Novak, Gowin & Johansen, 1983; Horton et al., 1993; Prezler, 2004). In regards to the use of concept maps in formal science assessment however, serious problems have been identified and limited its use for such purposes (Ruiz-Primo & Shavelson, 1996; Ruiz-Primo, Schultz, Li & Shavelson, 2001). Interestingly, concept mapping has also been shown to influence students’ attitudes and confidence in a range of contexts, such as: undergraduate biology (Prezler, 2004), medical education (Laight, 2004) and tertiary English as a secondary language (Chularut & DeBacker, 2004).

With the increased proliferation of computers into schools and the educational landscape over the last two decades (see Section 2.6), research into computer-based concept mapping has emerged. Within this field, the benefits of computer based concept mapping have been discussed (Anderson-Inman & Zeitz, 1993), and demonstrated (Bruillard & Baron, 2000; Chang, Sung & Chen, 2001). As a relatively modern development, the research on computer-based concept maps is far less extensive than that on ‘traditional’
concept maps. Regardless, the research concerning the use of computer-based concept mapping in science education has shown its benefits as a learning and instructional tool (Roth & Roychoudhury, 1993). McAleese (1994) suggests that these benefits arise from the support computers provide to the process of auto-monitoring during concept mapping. Indeed, computers offer unique capabilities to concept mapping, such as the ability for fluent creation and ease of map restructuring.

2.3 Other mapping research

Other mapping techniques have been described in the research literature. Although supported by less research studies than concept maps, they are useful to consider.

Firstly, it is important to differentiate between ‘concept maps’ and the sometimes colloquially synonymous (and popular) ‘mind maps’ (Buzan, 1995). Mind maps, unlike concept maps, do not have ‘linking phrases’ to denote meaning in linkages, relying on proximity to denote classification or meaning. Other specified characteristics of concept maps are not present in mind maps, such as a hierarchical structure (where mind maps tend to be more radial around one title concept) or cross-links between different segments (mind maps do not have multiple links per concept). It is important to note that mind maps do not have a presence in the research literature.

Knowledge maps represent another field of mapping research. As another variant of node-linked knowledge representations, knowledge maps differ from concept maps and mind maps in their deliberate use of a pre-defined set of labelled links that connect ideas (for example ‘type of’ or ‘part of’) (O’Donnell, Dansereau & Hall, 2002). The main research findings on knowledge maps are: students have greater recall with knowledge maps versus text; students with low verbal ability and low prior knowledge benefit the most from knowledge maps; when used in a cooperative learning environment, students learned more effectively; and finally information presented in well structured maps is recalled better than when it is presented in less well-structured maps (O’Donnell et al., 2002).

2.4 Link maps

Recently, research undertaken within the School of Physics at the University of Sydney (Lindstrøm, 2006, 2010) has conceived a mapping tool called ‘link maps’. Link maps are graphical representations of knowledge that are similar to concept maps, but with specific consideration of the physics education context that they are employed in. The theoretical basis of link maps (as with concept maps to a lesser extent) lies in cognitive load theory (see Section 2.5), which addresses the role of memory and cognitive processing in learning. To this, link maps emphasise the connection and relationships between key physics ideas, seeking to cue in student memory and develop beneficial schemata (Lindstrøm & Sharma, 2009).

Although they share similarities, there are distinct differences between link maps and other mapping tools. Primarily, these differences are due to the focus of link maps on representing the subject-specific features of physics knowledge. Physics knowledge has a unique and fluid knowledge structure, which can vary through its various sub-fields (such as mechanics, relativity or quantum physics). As such, genuine representation of physics knowledge can be difficult when attempting to fit such structures into the requirements of concept maps. Within concept maps, each node is only representative of the text within it — the physics-focused nodes of link maps however, are representative of much broader content, such as entire physical phenomena or laws. In link maps, links between nodes have linking words or phrases only when necessary, whereas these are mandatory in concept maps. Another point of difference is the presence of mathematical descriptions and equations, a fundamental component of physics, which are present in link maps but not in concept maps. Therefore, a key feature of link maps are their flexibility which allow them to conform to the nature of the physics they are representing (see Figure 2.2). It is hence argued that link maps are more suited to the needs of physics education than other mapping tools. Nonetheless, it is worthwhile to consider the large amount of research literature on concept maps and other mapping techniques when considering the development or implementation of link maps.
An integral feature of link maps, is that they serve to recreate what one might call an ‘expert’ knowledge structure. As such, link maps represent the way a physics expert might relate various components of his or her knowledge. Insight into such expert knowledge structures also allows an insight into how the expert would examine and solve problems (Jonassen, Howland, Marra & Crismond, 2008). In physics (and in other fields), the difference between an ‘expert’ and a ‘novice’ knowledge structure lies in the robustness of both the specific knowledge quanta and the connections between them (Bransford, Brown & Cocking, 2004). In the literature, this is often referred to as a difference in the way the knowledge is ‘chunked’. Consideration of this ‘chunking’ process is therefore vital in understanding how schema construction affects expert or novice performance (Gobet, 2005). This is the key consideration of link maps. By presenting expert schema in link maps, novices can be assisted in developing beneficial components and connections in their own knowledge structures.

Currently, implementation of link maps as a learning tool differs from the wide array of implementation utilised in the other types of mapping discussed. Implementation of link maps has focused on first year physics university students, in special enrichment tutorial sessions called ‘map meetings’ (Lindstrøm, 2006). Within these sessions, students were guided stepwise through the composition of a link map by an instructor, with student interactivity and input utilised in the process. Students were then given problems designed to develop their problem solving skills (with the aid of the link map), working through these in collaborative groups. To finish the session, the instructor would interactively explain problems identified by students as challenging. Findings on the effectiveness of link maps and map meetings has shown a positive effect on student achievement and self-efficacy² (Lindstrøm, 2010). Using measures of examination results and longitudinal surveys, findings show that link maps distinctly help novices in learning physics, with a statistically significant difference in the achievements of novices utilising link maps compared to novices who used more ‘traditional’ instruction methods (Lindstrøm & Sharma, 2009).

²Self-efficacy is a person’s sense of being able to deal effectively with a particular task (Woolfolk, 2005).
2.5 Cognitive load theory

Cognitive load theory (Sweller, 1988) is a research-based framework for examining learning as a function of human memory and processing. It provides guidelines to assist in the presentation of information in such a way that encourages cognitive activities in the learner that optimise intellectual performance (Sweller, van Merrienboer & Paas, 1998). Cognitive load theory is primarily concerned with two areas: the structure of human memory (cognitive architecture) and how information is processed (cognitive load).

The human cognitive architecture is widely acknowledged as composed of three memory systems: sensory memory, working (or short-term) memory and long-term (or permanent) memory (Novak, 1998):

- **Sensory memory** refers to the ability for sensory information to be retained after physical representations have ceased. It can be thought of as the momentary retention of visual and auditory information that an individual has focused on. Sensory memory has a significant capacity but a very short retention time.

- **Working memory** refers to the organisation and processing of sensory information by the brain. It is limited in both storage capacity and retention time. Working memory can be equated with consciousness, with humans conscious of and only able to monitor, the contents of working memory (Sweller et al., 1998). Miller (1956) was one of the first to make explicit the limits for working memory with the ‘seven plus or minus two’ rule — working memory is capable of holding and processing a maximum of about seven ‘chunks’ of information at a time\(^3\). Working memory is analogous to the role of a computer’s RAM in the processing of digital information.

- **Long term memory**, in contrast to working memory, has a massive storage capacity, and represents the virtually permanent information store in humans. Humans however, are not directly conscious of long term memory. Rather, awareness of the contents and functioning of long term memory is filtered through working memory. The role of long-term memory is analogous to that of the role of a computer’s hard disk in computational processing.

The structure of long-term memory is that of ‘schemata’, cognitive constructs that allow multiple elements of information to be categorised as a single element (Sweller, 2005). Schema theory (Rumelhart, 1980) contends that knowledge is stored in information packets that comprise our mental constructs for ideas, and it is the interrelationships between these schemata that gives meaning. ‘Accretion’ is the process in which schemata are acquired or changed, and as such is the ultimate goal of instruction. The process of accretion is the interface between long term and short term memory (R.C. Clark, Nguyen & Sweller, 2006)\(^4\). Importantly, the more knowledge and skills stored in more complex schemata, the greater the virtual capacity of working memory. This is because new information can be broken down into a smaller number of chunks. For example, it is much easier to process the kinetic theory of gasses; if the learner can link their schema of atomic theory, with the schema of motion and Newton’s laws. This all leads to a somewhat intuitive, but nonetheless important result — prior knowledge structures play a significant role in learning.

When considering cognitive processing, which occurs primarily in working memory, the amount of processing an individual has to allocate to a task is referred to as the amount of ‘cognitive load’. Consideration of how this cognitive load affects learning is one of the core purposes of cognitive load theory. The three types of cognitive load are (R.C. Clark et al., 2006):

- **Intrinsic load** — the inherent mental work imposed by the demands of the content (Chandler & Sweller, 1991). This is primarily determined by the instructional goals, as well as the knowledge and skill associated with an instructional objective. It is the difference between doing simple addition or deriving the speed of light from Maxwell’s equations.

\(^3\)An example of such processing on a simple level is the memorisation of random words, where the words represent chunks of knowledge. These chunks can be thought to be composed of ‘bits’; the letters that make up the words. However when no chunking is available (such as in the case of memorising random letters), the individual ‘bits’ are considered.

\(^4\)In this literature review there are two Clarks: R.E. Clark and R.C Clark.
• **Germane (or relevant) load** — the mental work imposed by instructional activities that benefit the instructional goal through the acquisition of schemata (Sweller et al., 1998). It is a relevant load imposed by instructional methods that leads to better learning outcomes. It can be thought of as the mental effort used to form schemata and actively integrate new information with prior knowledge. It is the difference between a student copying information out of a textbook (low germane load), or designing and carrying out an experiment (high germane load).

• **Extraneous (or irrelevant) load** — the mental work that is irrelevant to the learning goal, imposed by the instructional designer, in the structure and presentation of information (Chandler & Sweller, 1991). Consequently, it wastes the limited mental resources of working memory, draining capacity that could be used for relevant load. Messy handwriting is an example of extraneous load, with a lot of mental effort required to decipher meaning, for no useful purpose.

Effective instruction therefore lies in the optimisation of cognitive load within the limited working memory capacity of learners. If this limited capacity is overloaded (cognitive overload), schema acquisition will be impaired, resulting in lower performance (Sweller, 1988). This is the basic tenet of cognitive load theory — effective learning can be accomplished by managing intrinsic load, reducing extraneous cognitive load and increasing germane load (Kalyuga, 2009), all within the limited processing available to working memory (see Figure 2.3).

![Figure 2.3: Model for efficient learning (R.C. Clark et al., 2006).](image)

In the Australian context, research by Muller, Sharma & Reimann (2008) has utilised cognitive load theory as a framework for examining how to best teach physics concepts (like Newton’s Laws) through video multimedia. They found that the increasing of germane load in students by the raising of alternative conceptions, led to an increase in post-test scores, when compared to standard lecture-style presentations. This type of research is an example of how cognitive load theory can be utilised as a theoretical framework for research into both physics education and educational multimedia.

Critiques of cognitive load theory are rare in the research literature. However, Schnotz & Kurschner (2007) believe that there are conceptual problems with the foundations of cognitive load theory. Nonetheless, Schnotz & Kurchner advocate a re-evaluation, rather than an abandonment of cognitive load theory. Indeed, the research literature accepts cognitive load theory as valid, and as a useful theoretical foundation for examining the processes of learning.

### 2.6 Educational multimedia

The success of projects such as the PhET physics/science simulations initiative, headed by Nobel Laureate Carl Wieman (Wieman, Adams & Katherine, 2008) suggests that multimedia has a significant yet
untapped potential in physics education. What exactly ‘educational multimedia’ is however, is important
to define, as it can mean different things to different people. The definition that is most pertinent to this
discussion is that put forward by the figurehead of multimedia learning, Richard Mayer. Mayer (2009)
defines multimedia as material which uses both words and pictures. Words can be presented either ver-
bally or with text. Similarly, pictures can be presented either statically (such as in diagrams, graphs of
photos) or dynamically (such as in animations or videos). With this definition, multimedia spans a large
array of the tools utilised in physics (and science) teaching — from textbooks, to videos and computer
programs. However in the modern context (and in this thesis), multimedia is synonymous with the more
technology-dependent tools, such as videos and computers.

There has always existed a type of cynicism with ‘new’ educational multimedia tools (see discussion
in Romiszowski, 2004), and much ink has been spilt concerning the effectiveness of various multimedia
in their differing incarnations. As Cairncross & Mannion (2001) point out, the richness and capabilities
of multimedia can lead to problems if the needs of the learner are not carefully considered. Indeed, the
fundamental claim of cognitive load theory is that unless the underlying cognitive architecture of the
learner during instruction is considered, effectiveness is likely to be limited. The dangers of this lay in
an environment in which technology generates the learning experiences, rather than the consideration of
cognitive processes guiding the use of technology for instructional purposes (Chandler, 2004). This point
is especially pertinent when considering the tendency in the past, for the design and use of educational
multimedia to be based on intuition rather than research-based principles (Ploetzner & Lowe, 2004).
Coupled together, these factors provide a recipe for an inevitable failure of educational multimedia, to
the expectations of the cynics.

One of the fundamental debates about educational multimedia concerns the influence of the type of
media on learning outcomes. This debate is framed most influentially by the opposing views of Richard
Clark and Robert Kozma. It is essentially a debate over the ‘medium being the message’ — whether
different types of media shape learning differently (Kozma, 1994), or that the ‘replaceability’ of media
characteristics sees the form of media as irrelevant (R.E. Clark, 1994). In lieu of the hype, numerous
studies demonstrate little weight behind the proposal that computers yield more learning than books,
teachers, films or other traditional methods (Alessi & Trollip, 2001; R.E. Clark & Feldon, 2005). To this,
Muller (2007) discusses an ‘equivalence principle’ — relevant cognitive processes are indistinguishable
if different formats or multimedia are appropriately chosen.

As such, the current understanding of the importance and value of multimedia is still very much
debated. However work by Richard Mayer and many other researchers has seen the development of a
methodology for effective multimedia practice, through a ‘cognitive theory of multimedia learning’. The
development of this is summed up in The Cambridge Handbook of Multimedia Learning (Mayer, 2005),
which brings together all the work that has been done in the area. This ‘cognitive theory of multimedia
learning’, merges notions of educational psychology, cognitive load theory and multimedia learning, all
within the framework of empirical scientific research.

Multimedia learning theory is based upon three fundamental assumptions (Mayer, 2009). Firstly
it rests on the dual-coding theory (Paivo, 1986), which states that humans possess separate channels
for processing visual and auditory information. The second assumption, is that humans are limited in
the amount of information that can be processed in each channel at one time (Sweller, 1999). Lastly,
the active-processing assumption — humans engage in active learning by attending to relevant incoming
information, organising selected information into coherent mental representations, and integrating mental
representation with other knowledge (Wittrock, 1989). The interactions of these assumptions with the
human cognitive architecture of cognitive load theory is shown in Figure 2.4.

The cognitive theory of multimedia learning research has yielded various ‘multimedia principles’
to be considered when designing educational multimedia. Mayer and his colleagues arrived at these
principles through empirical experiments which saw participants interact with various multimedia, with
the independent variable the ‘principle’ in question. Participants were then given retention and transfer
tests to see which methodology was most beneficial (Mayer, 2009). These principles can be used in
managing intrinsic load, reducing extraneous load or in considering germane load (see Figure 2.3)

Some of the multimedia principles, relevant to this study include (Mayer, 2005, 2009):

• *Multimedia principle* — people learn better from words and pictures than from words alone.
Figure 2.4: Cognitive theory of multimedia learning (Mayer & Moreno, 2003)

- **Modality principle** — people learn better from graphics and narration than from graphics and printed text.
- **Pre-training principle** — people learn better from a multimedia message when they know the names and characteristics of the main concepts.
- **Segmenting principle** — people learn better when a multimedia message is presented in learned-paced segments rather than as a continuous unit.
- **Split attention principle** — people learn better when words and pictures are physically and temporally integrated. This has often also been mentioned as the contiguity principle; that people learn better when corresponding words and pictures are presented near, rather than far from each other visually or in time.
- **Redundancy principle** — people learn better when the same information is not presented in more than one format (such as with audio and text).
- **Coherence principle** — people learn better when extraneous material is excluded rather than included.
- **Personalisation, voice, and image principles** — people learn better when words of a multimedia presentation are in conversational style rather than a formal style and when the words are spoken in a standard-accented human voice. However, people do not necessarily learn better when the speaker’s image is on the screen.
- **Animation and interactivity principles** — people do not necessarily learn better from animation than from static diagrams

In the Australian context, research projects in physics education have demonstrated the efficacy of Mayer’s principles in the design and use of multimedia at both high-school and tertiary levels (Mayo, Sharma & Muller, 2008; Muller, 2007; Muller, Lee & Sharma, 2008).

### 2.7 Issues in high school physics education

Within the context of learning physics in high school, there are distinct issues that affect student learning. A synthesis of six meta-analyses shows that motivation, self-concept and interest play a significant role in ensuring positive student outcomes (Hattie, 2009). This is important to consider for physics educators, as physics has always been regarded as a difficult and abstract subject, accessible only to those who have a special aptitude for science and mathematics (Rieber, Tzeng & Tribble, 2004). This is especially important as it has been shown that students attitudes and beliefs about physics have a positive correlation to their success with physics (Sadler & Tai, 2001). To address this, validated surveys on student attitudes and beliefs about physics have been developed and used at a tertiary level (Adams, Perkins, Podolefsky, Dubson, Finkelstein & Wieman, 2006; Redish, Saul & Steinberg, 1998). Findings from such surveys
show that students often have conceptions and views about physics which differ greatly from those possessed by physics experts. Unfortunately, these ‘inaccurate’ views and conceptions have been found to sometimes not change after a semester of instruction — a significant issue for physics educators. Within the literature, such types of studies in examining attitudes and beliefs of high school physics students have not been undertaken.

High school physics education is the focus of this thesis. The high school context is the New South Wales Higher School Certificate (NSW HSC), in which students opt to choose to study HSC Physics as part of their final secondary qualification. The HSC Physics course (NSW Board of Studies, 2010) is composed of two years; a ‘preliminary’ year which is completed prior to the ‘HSC’ year. Only the content covered in the HSC year is assessed at the end of students’ secondary studies, and this mark goes towards their university admission score (Australian Tertiary Admission Rank or ATAR). Because of this, the HSC content is considerably high-stakes and the related teaching, learning and revision reflects this. Therefore, the material for this research project addresses core material that had been identified by high school physics teachers as difficult to teach and revise.

2.8 The literature and the research question

The literature discussed in this review provides a research-based framework for effective teaching and learning strategies in high school physics education. This research project has been novel in its approach — to integrate a wide range of research areas in examining how high school physics can be improved. Specifically, the research questions that this project examined were:

1. Can link maps be successfully integrated into computer-based and video-based multimedia tools for high school physics education?
2. How do link map based multimedia affect high school physics students’ attitudes, achievement and knowledge structure?

This research project answers these questions by developing and implementing computer and video tools in accordance with Mayer’s design principles (2005; 2009). The physics content in the multimedia focused on a challenging HSC topic; ‘the motor effect’. The tools were developed to aid in revision, and through the link maps provide students with experiences with ‘expert’ schemata, to aid in their own schemata development. By doing so, the tools hoped to change students attitudes and beliefs about physics. The effects of the tools on student schema formation, and achievement on test questions will also be examined, as will teachers’ and students’ views on the tools. Finally, a comparison of the effects of the computer-based and video-based multimedia tools will be presented.
Chapter 3

Multimedia development

3.1 The link maps

Three link maps focusing on content from the HSC Physics syllabus were developed for this research project. The link maps were developed based on the teaching experiences of the researcher, discussions with high school physics teachers, and advice from the SUPER group. The topics addressed in these link maps were: ‘the motor effect’, ‘electromagnetic induction’ and ‘special relativity’. These topics were chosen due to the difficulty high school students experience in integrating knowledge into coherent knowledge structures for these areas of the HSC syllabus. Due to time and scope constraints, only the link map on ‘the motor effect’ was fully developed into the multimedia tools and comprehensively evaluated.

The three developed link maps can be found in Appendix A. As mentioned, the central idea behind link maps is the representation of an experts’ schemata on the physics content in question. Considering the HSC syllabus and the expert knowledge base of the development team, in the topic areas examined, the ‘expert’ schemata was hierarchical and interrelated, often moving gradually from ‘laws’ to real world examples. As with these and previous link maps (see Section 2.4), an important component of link maps is the way in which various components of the knowledge (laws, equations, concepts, applications, etc.) are denoted. As such, a ‘key’ was also produced as a guide to the various types of shapes and components used throughout the three link maps (included in Appendix A). The colours used in the link maps were modified to make them more readable by those with red-green colour-blindness (≈10% of the male population). Green text was also underlined to aid differentiation from orange text. The created link maps were ‘tested’ on a colour-blind male who was able to discern differences under minimal examination.

The use of expert-composed maps, as opposed to allowing students to create their own, is characteristic of link map research (Lindstrøm, 2006, 2010; Lindstrøm & Sharma, 2009). On this topic, the findings from the concept map literature are inconclusive. Indeed Prezler (2004) states that: “the most effective organisation of a domain of knowledge for a student may be very different to the organisational scheme used by an expert”. Similarly Horton et al. (1993) found the strongest effects on achievement occurred when students provided the terms for the maps, regardless of who (individuals, groups or teachers) then constructed the maps. However, other research has found higher achievement effects for teacher-generated, rather than student-generated maps (Kim, Vaughn, Wanzek & Wei, 2004). Indeed, high school and university students often have difficulty creating good concept maps (Novak, 1998), and it has been shown that students with little prior knowledge in a domain do not necessarily make good decisions when it comes to their own learning (Rieber et al., 2004). Additionally, Gurlitt & Renkl (2008), demonstrated that when using concept maps, high school students benefit from more scaffolding (i.e. providing labelled lines). With the issue unresolved in the concept map literature, the decision to use expert-composed link maps was a research decision. The rationale for this decision was: by presenting expert link maps, novices can be assisted in acquiring beneficial components and connections in their own knowledge structure.

Creation and use of the link maps in this project was also grounded in concept map research. For example, the simple structure of link maps, aiming to emphasise the underlying simplicity of physics — agrees with findings that there are beneficial effects when emphasis is on understanding the central rather than the detailed ideas of a topic being concept-mapped (Nesbit & Adescope, 2006). In regards to the link map multimedia tools aimed at being revision tools, the concept map literature has found benefits in
using concept mapping after initial exposure to the material to be mapped (Moore & Readence, 1984).

3.2 Multimedia design principles
The design and creation of the video and computer tools rested on a number of common design principles:

- Emphasis of the native features and capabilities of the computer and video mediums, was a key design consideration born out of a key research decision. The video tool would focus on being personable, aimed at whole-class viewing and broken up into slices (which has shown to be beneficial for learning high school physics (Mayo et al., 2008)). On the other hand, the computer tool would harness the natural interactivity, user control and feedback mechanisms of computer-based multimedia. The reason for this research decision, was to circumvent the ‘multimedia debate’ about the influence of the specific medium. Instead, this study took the novel approach of designing tools to exploit the specific medium’s native features, rather than trying to ‘match’ the content in each multimedia.

- Interactivity was another common design principle, as concept map research has shown beneficial effects when students are made to construct, rather than just study concept maps (Nesbit & Ade scope, 2006). It was therefore necessary to ensure that both the multimedia tools allowed students to compose a link map. The computer tool was hence developed to ensure students would be able to compose a link map within tool. The video tool on the other hand — whose native features does not lend the same level of interactivity — utilised a ‘real-life’ link-mapping activity using provided cardboard pieces, in between video slices (similar to Mayo et al., 2008).

- Cognitive load was another key consideration of the multimedia design. If a multimedia tool leads to cognitive overload in learners, its instructional value sharply drops. Educational multimedia tools are much more susceptible to promoting cognitive overload when their development relies on craft-based, rather than research-based principles. This is because modern multimedia tools have a capacity to deliver an large amount of content in a very short time. To address this, our multimedia utilised multimedia design principles born out of the ‘cognitive theory of multimedia learning’ (Mayer, 2005) (discussed in Section 2.6). These principles served as the overarching framework for the development of both the video and computer tools, with medium-specific design principles discussed in Sections 3.3 and 3.4.

- Finally, real-world applicability guided the design of the multimedia tools. Therefore, the tools were developed such that their implementation would be pedagogically sound, and practical in common high school contexts. For example, both the multimedia tools where limited in their duration such that their use could be contained within a typical-length lesson (from 40–80 minutes). Additionally, the hardware requirements for both the tools were tailored to fit the hardware infrastructure of typical high schools.

3.3 The computer tool
3.3.1 Details of the computer tool
A key native feature of computers is the interactivity that they can provide for learning (Kalyuga, 2009). Therefore, the focus of the computer tool was to facilitate students’ interactivity with the tool, in composing link maps and receiving feedback. The most suitable platform for the computer tool was ‘Flash’, a common delivery platform for interactive content, easily accessible though the majority of internet browsers. The final computer tool was comprised of a number of distinct stages:

1. A narrated tutorial which introduced students to link maps, the ‘key’ and led students through an example of composing a link map. Research has shown that if this is not done, the abilities for a novice to interact with computer-based learning objects is greatly limited (Lowe, 2004).
2. A ‘composition’ exercise which facilitated students in arranging a scaffolded link map on ‘the motor effect’ by dragging and dropping components onto a ‘skeleton map’ (see Figure 3.1(a)). Students could then check their answers and receive feedback, until all the components were correctly placed.

3. An ‘exploratory’ screen which provided students with an opportunity to explore the components of the link map in more detail (Figure 3.1(b) and Figure 3.1(c)). By clicking on various components of the link map, students would hear explanations of the component and how it fitted into the overall link map structure.

4. Another ‘composition’ exercise, but now with a larger number of different components missing (Figure 3.1(d)).

5. The same ‘exploratory’ screen as in 3.

6. A chance to restart or finish using the computer tool.

Figure 3.1: Screenshots from the computer tool. (a)(top left) the first composition exercise; (b)(top right) the exploratory screen; (c)(bottom left) an example of an explanation; and (d)(bottom right) the second composition exercise.

3.3.2 The development process

The development of the computer tool, scripting and narration was undertaken by the researcher, but due to time constraints and lack of sufficient experience, the 
Flash programming was undertaken by an external developer. The process of creating the computer-based link map tool took a couple of months, ranging from; initial discussions and meetings about the feasibility of putting link maps into a virtual environment, to discussions about suitable platforms, and finally to many feedback iterations between the researcher and the developer.

The development stage utilised 
PowerPoint to create a mock-up of the functioning of the computer program; encapsulating the look of the program, the user interface and how various components would run. The SUPER group were consulted on numerous occasions during this stage of development, with suggestions and feedback integrated over a handful of iterations. This mock-up was then presented to the developer as a template for the actions and sequencing of the tool. To supplement this, a set of more
specific instructions, detailing input options, button function, audio, timing and actions were provided (Appendix B). Audio narration would feature in the computer tool, so a script was created (Appendix C) and provided to the developer. Using the script, the narration for the program was narrated and recorded by the researcher. These audio files were also provided to the developer.

With all of the necessary components completed by the researcher, the developer took about a month to complete the first computer tool. This tool was reviewed by the researcher and the SUPER group with feedback returned to the developer. The computer tool was finalised over several feedback iterations, with a development time from start to finish of about four months. For ease of access for student participants, the computer tool was stored online to be run online or downloaded. The program was also stored on a number of portable USB memory sticks for use in schools.

### 3.3.3 Consideration of Mayer’s design principles

In the design of the computer tool, a number of relevant ‘multimedia principles’ were considered:

- The **multimedia principle** is prominent throughout the computer tool, with narration and text used with pictures (the components of the link map serving as quasi-pictures). In this, the **split-attention principle** was used, with words (both text and narration) physically and temporally close to the related visuals.

- Integral to the computer tool was the **modality principle**. This saw audio narration as heavily featured, favoured over text to describe what was going on in the tool. Such narration was delivered in accordance with the **personalisation and voice principles**. The **redundancy principle** was also used, with narration not duplicated in text and vice versa (with the exception of the first few screens; a decision made due to the very low cognitive load in those screens).

- In terms of the **segmenting principle**, the computer tool was designed to allow its message to be presented in learner-paced segments. Buttons would allow students to choose to proceed or replay certain sections.

- The **pre-training** principle was also utilised in the computer tool, with the tool starting with a tutorial-like introductory run-through. This would ensure students would be primed for the rest of the tool, with the ability to be able to discern what was going on in an otherwise unfamiliar tool.

### 3.3.4 Other considerations

The computer tool was designed to be used by individual students using headphones to deliver the audio, a native feature of computer-based multimedia. Additionally, some craft-based design principles for computer-based multimedia, put forward by Alessi & Trollip (2001) were also utilised. The computer tool has a user-controlled title screen, which has no content to be learned and included: the title, author, owner name, copyright and a button to exit. As mentioned, functionality was present to allow students to choose when to proceed. The ability to allow users to exit from anywhere within the computer tool was also included.

### 3.4 The video tool

#### 3.4.1 Details of the video tool

Video-based educational multimedia has been prominent in physics education for a long time — starting long before the increased popularity of computers. Video tools have a number of native features that differentiate them from computer-based multimedia. Firstly, educational videos are highly portable and viewable on a large range of devices (televisions, projectors, computer). Videos are also less dependent on technology, both in the quality and quantity required, (a problem that computer-based multimedia often encounter). Another, native feature is video’s ability to portray personality, which saw the video-based multimedia able to emulate the instructional processes present in ‘map meetings’ (Lindstrøm & Sharma, 2009) (see Section 2.4).
The video tool was designed and put together by the researcher, with help from Dr. Derek Muller. The final product was composed of the following segments:

1. The presenter walks students through an introduction to link mapping, discussing the ‘key’ (Figure 3.2(a)). The presenter then moves stepwise through a composition of an example link map, explaining how link maps work (Figure 3.2(b)).

2. The presenter prompts the students to the group activity, in which they compose a real life link map on ‘the motor effect’. This is the end of the first ‘slice’.

3. (Students participate in link map composition in small groups using provided cardboard pieces).

4. The presenter walks students through the composition of ‘the motor effect’ link map (Figure 3.2(c)), explaining how each of the components fits into the overall link map composition (Figure 3.2(d)).

5. The presenter prompts student to make any corrections to the real life link map they composed.

6. The presenter thanks students for their time and the video ends.

Figure 3.2: Shots from the video tool. (a)(top left) the introduction to link mapping; (b)(top right) continuing the tutorial, composing an example link map; (c)(bottom left) walking through the composition of ‘the motor effect’ link map; and (d)(bottom right) explanation of each component of the link map.

3.4.2 The development process

The first step in developing the video tool was the storyboarding of what the video tool would look like. With this, a script and outline was also produced to aid in the shooting of the video (see Appendix D). A complementary PowerPoint presentation (similar to the one developed for the computer program) was also created to support the presentation of the link map in the video tool (this is what is seen in Figure 3.2).

The filming of the video tool occurred at a classroom in Chatswood. This location was chosen due to the availability of an ‘interactive whiteboard’, which would display the complementary PowerPoint during the presentation. The researcher presented the material, while Dr Derek Muller did the camera work. Shooting took a couple of hours, with enough raw footage taken for later editing. Dr Derek Muller with help from the researcher, edited the raw footage into the final video tool product. This was done using Final Cut Pro, with the resulting video tool posted on YouTube for ease of access and on a number of USB memory sticks. The time-frame for the development of the video was substantially less than that for the computer program. Although the development phase was about the same for both multimedia, the video took much less time to actually put together into the final product.
3.4.3 Consideration of Mayer’s design principles
In the design of the computer tool, a number of relevant ‘multimedia principles’ were considered. Due to the consideration of the native features of video mediums, the application of these principle has both similarities and differences to those discussed in Section 3.3.3:

- The *multimedia principle* was again prominent in the video tool, with narration (from the presenter) and text used with pictures (quasi-pictures if considering the components of the link map). With this, the *split attention principle* was used, with words (both text and narration) physically and temporally close to the related visuals.
- The *modality principle* was also integrated into the video tool, with the presenter’s narration utilised to describe what was going on during the video.
- Within the native features of video based multimedia, emphasis was given to the *personalisation* and *voice principle* in regards to how the presentation was made. Also related, the *redundancy principle* was used, with narration not explicitly duplicated in text and vice versa (other than the repetition of the necessary terms within the nodes of the link map).
- As with the computer tool, the video tool also provided an introductory tutorial to link mapping, in accordance with the *pre-training principle*.
- The *segmenting principle* although not strictly followed, was adapted to fit within the native features of the video tool. For example, the decision to break the video into slices added a degree of segmenting. Additionally, the video tool aimed to build-in the learner-paced part of the *segmenting principle* by ensuring that the pace of the presenter and visuals was appropriate for the target audience.

3.4.4 Other considerations
As with the computer tool, the development of the video tool also took other design considerations on board. The most obvious of these was the slicing of the video tool into segments. Other considerations including the shot angle, timing, lighting and transitions were all incorporated in the help provided by Dr Derek Muller.

3.5 Comparing the tools
In summary, it is useful to compare the details of the two multimedia tools. This is shown in Table 3.1.

<table>
<thead>
<tr>
<th>Details</th>
<th>Computer tool</th>
<th>Video tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participation</td>
<td>Individual</td>
<td>Whole class (watching video) and group-work (composing the map)</td>
</tr>
<tr>
<td>Slices</td>
<td>Different activities integrated within tool</td>
<td>Real life map composition in groups between video slices</td>
</tr>
<tr>
<td>Construction of link map</td>
<td>Virtually, with scaffolding and feedback provided by the tool</td>
<td>In real life, using provided cards within small student groups</td>
</tr>
<tr>
<td>Resources</td>
<td>Class set of computer/laptops plus headphones</td>
<td>Projector, screen and link map cards to compose</td>
</tr>
</tbody>
</table>

Table 3.1: Differences between the two multimedia tools.
Chapter 4

Evaluative framework

4.1 A note on pre- and post-tests

The basis of the evaluative framework used in this research project is a pre- and post-test methodology. This means that the same evaluative tools, whether it be a survey on students’ learning attitudes and beliefs, student-generated map or test question — are given to student participants before and after their interaction with the multimedia tools. By doing so, this type of technique is used to gain an insight into the effect of the multimedia tools on the students.

It is worth noting, that this experimental design is common in educational and social research (Neuman, 1995). However with this methodology, the common question often arises: “Don’t the students just remember the pre-test, decreasing the validity of the post-test?” Past physics education research on the pre- and post- methodology, has found that there are no effects from students ‘remembering’ (Henderson, 2002). Henderson (2002) found, that there was indeed no statistically significant difference in post-test scores between groups which where exposed to the pre-test compared to groups which were not. The pre- and post-test design is a widely used method and one selected for assessing the effects of the multimedia tools in this research project. To further strengthen the methodology, triangulation of results from a number of different measures was used.

4.2 The CLASSh: Surveying students’ attitudes and beliefs about physics

A key part of the research project was the examination of the impact that the developed multimedia tools did or did not have on students attitudes and beliefs about physics. To do this, previous research on the area was considered. From this, a specific instrument for our research context was developed

4.2.1 Past research in exploring tertiary physics students’ attitudes

The evaluation of students’ views, attitudes and expectations has been an area of interest for researchers for a few decades. Primarily, this interest has stemmed from the realisation that students’ achievement in physics courses may be affected by such attitudes and beliefs. To probe these attitudes and beliefs, several statistically validated surveys have been developed by various physics education research groups to be implemented in the university context. These include the Maryland Physics Expectations (MPEX) survey (Redish et al., 1998); the Views About Science Survey (VASS) (Halloun, 2001) and the Epistemological Beliefs Assessment about Physical Science (EBAPS) (Elby, Frederiksen, Schwarz & White, 1997). As the names suggest, these validated surveys sought to explore how students viewed the subject of physics, with each having a particular focus (primarily aspects of epistemology or expectations) as well as a focus on either breadth or depth.

The most recent attempt at exploring students attitudes and beliefs is the Colorado Learning Attitudes about Science Survey (CLASS ) (Adams et al., 2006). The CLASS utilises five-point Likert scale items in which participants would select their level of agreement/disagreement with a statement. The CLASS has specific characteristics which set it apart from the MPEX, VASS and EBAPS such as (Adams et al., 2006):
1. A wider set of influential factors (rather than just expectations or just attitudes) are considered.

2. The wordings of the statements were constructed and tested to ensure clarity and conciseness allowing them to be subject to a single interpretation.

3. Statements are written to be meaningful to all students, even those with minimal exposure to physics.

4. ‘Expert’ and ‘novice’ responses to each statement can be unambiguously and easily distinguished.

5. Survey length was limited for completion within ten minutes, with ease of administration and scoring emphasised.

6. The grouping of statements into categories was done via an exploratory factor analysis, with only robust categories accepted into the final survey. These categories were composed of groups of statement which represented a distinct facet of student attitudes and beliefs about physics. The eight CLASS categories included: real world connection, personal interest, sense making/effort, conceptual understanding, applied conceptual understanding, problem solving (general), problem solving confidence and problem solving sophistication.

The CLASS has been designed to be implemented in a pre- and post-test manner, to examine the shift in students’ beliefs after various learning experiences, such as a semester of instruction. The CLASS also allows for correlations to be made between pre-test results and other influential factors such as age, gender or course selection. Published survey results have centred around examining the effects of a first-year university physics education on students — however, a key stated purpose of the CLASS is its adaptability to other science areas (such as biology or chemistry). Therefore, we chose the CLASS for its: relevant categories to our research, rigorous statistical validation, stated flexibility in implementation and examination of ‘expert’ and ‘novice’ attitudes and beliefs. The CLASS framework was the basis for the development of the ‘CLASSh’ (h for high school), which was used to evaluate the effects of the link map multimedia.

4.2.2 The development of the CLASSh

The CLASSh was developed to assess the effect of the multimedia tools on high school physics students ‘expert’ or ‘novice’ attitudes and beliefs about physics. The link mapping presented in the multimedia emphasised certain aspects of how experts view physics; specifically the interconnectedness of the content and their links to real-world applications. To preserve the statistical validity of the CLASS, all the items for each relevant category were extracted into the CLASSh. The CLASS categories used in CLASSh were: ‘real world connections’, ‘conceptual connections’ and ‘applied conceptual understanding’. Examples of such items from these categories include:

- **Real world connections category** — “Learning physics changes my ideas about how the world works.”

- **Conceptual understanding category** — “Spending a lot of time understanding where formulas come from is a waste of time.”

- **Applied conceptual understanding category** — “If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.”

Overall, the CLASSh was composed of 14 Likert scale items, including one ‘discriminator’ item (see Appendix E for the full survey). The purpose of the discriminator (item 10) was to allow for the discarding of survey responses in which participants did not properly read the statements. In addition to the 14 items sourced from the CLASS, data was taken on name and gender. The only purpose of collecting this data was to allow a matching of students pre- and post-surveys.
4.3 Student-generated mapping

Concept maps have a history of use as a method of analysing student knowledge structures (in non-summative assessments) (Jonassen et al., 1993). Indeed, concept maps have been used in physics education research as an effective non-formal evaluation of student knowledge structures. For example, Hogg (1999) utilised concept maps to investigate student understanding of physical optics. Similarly, Fletcher (2004), in investigating how to best teach quantum mechanics, used concept maps to assess university students’ understanding of quantum mechanics. Fletcher used the structure of student-composed concept maps to gauge students’ knowledge structure, developing a categorisation to classify such maps (see Appendix F).

In this research, Fletcher’s (2004) categorisation is utilised as a means of evaluating students’ knowledge structures as affected by the link map tools. To do this, students were asked to compose maps representing their knowledge on ‘the motor effect’ before and after using either of the multimedia tools. These maps were then analysed for shifts in structural complexity, providing a mechanism for examining the effects of the multimedia on students’ knowledge structures.

4.4 Test question

Another aim of the research project was to determine if there was any change in student achievement due to the multimedia tools. To do this, a pre- and post-test question was used. This test question (see Figure 4.1) was sourced from the 2006 HSC exam (the final exam for Year 12 students). It was chosen from a number of potential test questions due to its relation to the material addressed by the link map multimedia tools. Importantly, the question also requires students to synthesise a number of concepts on ‘the motor effect’ to successfully answer the question. The test question was marked out of 4 (with half-marks possible) according to a marking criteria validated by experienced HSC exam markers (see Appendix H).

Instructions
The following is a question from the 2006 New South Wales Higher School Certificate Exam. Please answer it as best you can within the time given.

Question
The diagram shows the structure of a typical galvanometer.

Describe how the galvanometer operates as an application of the motor effect.

Figure 4.1: Test question (full version in Appendix G).
4.5 Teacher feedback

Teachers are a key factor in regards to the implementation and uptake of multimedia in physics (or other) classrooms (Dexter, Anderson & Becker, 1999). Therefore, the views of teachers also need to be considered, and to do this, a questionnaire was prepared and given to the teachers of the classes participating in the study. In all cases, the teachers were present when their students interacted with the multimedia. Teachers were given the opportunity to take their time completing the questionnaire via email, and were given access to the multimedia for review if necessary.

The questions posed were as follows:

1. How many years experience do you have in teaching physics? What is your background?
2. Do you think the organisation of concepts into coherent structures is a common problem or issue with your students?
3. How confident are you with teaching physics in this way? Or confidence in general?
4. Do you think that link maps provide a way to help students organise their knowledge?
5. How effective do you think the link map tools your students used were? Do you think they serve better as a revision tool, or in some other capacity?
6. Do you notice any gender differences in your students with regards to the organisation of physics schemata?
7. Do you have any suggestions of how link maps, or the link map tools could be improved?
8. Do you have any comments on the use of technology in things like the link map tools?
9. Do you have any general comments about the link map, or the link map tools that your students used?

4.6 Student feedback

Student feedback on the multimedia tool is also valuable in assessing the pedagogical viability of the developed multimedia tools. To do this, an open-ended free-response section was included at the end of the post-CLASSh (see Appendix I). It asked student participants to leave any comments (positive or negative) on how they found the multimedia tool they used. Such open-ended items are commonly used in qualitative research (Silverman, 2005). The NVivo computer program (which has been developed to analyse text-based qualitative data) was utilised in analysing student responses.

4.7 Mental effort

By analysing students perceived mental effort, we gain insight into the total cognitive load invested in interacting with the multimedia. This is important, as the amount (and type) of cognitive load is strongly related to beneficial learning outcomes (see Section 2.5). In measuring cognitive load, past research has utilised many different measurements, such as rating scales, psycho-physiological measure, or secondary task techniques (Paas, Tuovinen, Tabbers & Van Gerven, 2003; van Gerven, Paas, Van Merriënboer & Schmidt, 2004). Self-reporting scales, in which students report the amount of mental effort they invest in a task (i.e. their cognitive load), are the most appropriate for our research. Although they might seem like the least reliable of cognitive load measures, such self-reporting scales have better sensitivity and reliability than some physiological measurement methods (Paas et al., 2003).

In research into the the effects of multimedia on teaching Newton’s laws of motion — Muller et al. (2008), used a simple 9-point Likert scale item to gauge perceived student mental effort. This research utilised the same item (see Figure 4.2) to evaluate any differences in perceived mental effort between students who used the computer tool and students who used the video tool.
4.8 Ethics

As with all research conducted with humans via the University of Sydney, ethics approval for our research was necessary. Details of the approval granted by the Human Research Ethics Committee are provided in Appendix J.
Chapter 5

Interventions and data collection

5.1 Data sources
Various schools throughout Sydney provided participants for the research. All participants were Year 12 students, with all participants having covered and been assessed on ‘the motor effect’ topic. The participant groups\(^1\) and number of student participants\(^2\) are detailed in Table 5.1.

<table>
<thead>
<tr>
<th>School</th>
<th>Multimedia tool used</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Computer</td>
<td>12</td>
</tr>
<tr>
<td>2 (3 classes)</td>
<td>Computer</td>
<td>49</td>
</tr>
<tr>
<td>3</td>
<td>Video</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>Video</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>Video</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 5.1: Participating schools.

5.2 Structure of interventions
Data was collected by the researcher, going to the participating schools and running the ‘intervention’, where students were exposed to a multimedia tools and the various evaluative instruments. To ensure consistency, the timing for the various steps in the process was planned and followed for both multimedia (see Table 5.2). The total time taken for the interventions (including turn-around time between steps) was approximately 60 minutes.

The only significant difference between the computer and video intervention lies within what the students are doing in the ‘multimedia participation’ step (Step 5 in Table 5.2). The differences were discussed in Section 3.3 and 3.4, and are summarised in Table 5.3.

5.3 Observational data during interventions
Observational notes were taken at each intervention to ensure that any anomalies in the data would be accounted for. Overall however, there were no major issues that affected the data collection, with all of the sessions going smoothly, bar the small number of students who did not appear to engage fully with the various evaluation tools.

\(^1\)School 1 in Table 5.1 did not undertake mapping or the mental effort item.
\(^2\)The number of students who interacted with the multimedia tools, not necessarily the number that provided useful data.
<table>
<thead>
<tr>
<th>Step</th>
<th>Time</th>
<th>Instrument used and procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 min</td>
<td>Introduction to study - ethics details</td>
</tr>
<tr>
<td>2</td>
<td>5 min</td>
<td>Pre-survey</td>
</tr>
<tr>
<td>3</td>
<td>5 min</td>
<td>Pre-test question</td>
</tr>
<tr>
<td>4</td>
<td>5 min</td>
<td>Pre-map composition</td>
</tr>
<tr>
<td>5</td>
<td>≈15-20 min</td>
<td>Multimedia participation</td>
</tr>
<tr>
<td>6</td>
<td>5 min</td>
<td>Post-map composition</td>
</tr>
<tr>
<td>7</td>
<td>5 min</td>
<td>Post-test composition</td>
</tr>
<tr>
<td>8</td>
<td>5 min</td>
<td>Post-survey</td>
</tr>
<tr>
<td>Post</td>
<td>via-email</td>
<td>Teacher questions</td>
</tr>
</tbody>
</table>

Table 5.2: Structure for data collection sessions.

<table>
<thead>
<tr>
<th>Step</th>
<th>Computer tool</th>
<th>Video tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td>Introduction</td>
</tr>
<tr>
<td>2</td>
<td>Self-paced link map tutorial</td>
<td>Presenter walks through a link map tutorial</td>
</tr>
<tr>
<td>3</td>
<td>1st scaffolded composition exercise</td>
<td>Participants compose a real life link map, using provided in cardboard pieces, in small groups of 2-3 students (See Figure 5.1)</td>
</tr>
<tr>
<td>4</td>
<td>1st exploratory section</td>
<td>Presenter goes through the composition of link map</td>
</tr>
<tr>
<td>5</td>
<td>2nd scaffolded composition exercise</td>
<td>Participants are given a chance to change their real life link map compositions</td>
</tr>
<tr>
<td>6</td>
<td>2nd exploratory section</td>
<td>Conclusion</td>
</tr>
<tr>
<td>7</td>
<td>Conclusion</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.3: A comparison of the ‘multimedia participation’ between the two tools (Step 5 in Table 5.2).
Figure 5.1: An example of the mapping task done in small student groups between video slices.
Chapter 6

Results and analysis

6.1 A note on analysis

6.1.1 Statistics

In analysing data from the various evaluative instruments, several statistical tests and methods were used. Statistical analysis and tests were done primarily using PASW (Predictive Analytic SoftWare) the most recent iteration of the widely used SPSS (Statistical Package for the Social Sciences). The main tests used to analyse the data were Shapiro-Wilk, Mann-Whitney and chi-squared tests. The Shapiro-Wilk test is used to determine whether data fits a normal distribution. The Mann-Whitney test is a non-parametric test, used to determine if there is a statistically significant difference in two independent data (ordinal or continuous) samples. Chi-squared tests are used to determine whether variation in nominal data is statistically significant.

6.1.2 Excluded data

As mentioned previously, not all the students who participated in the study provided usable data. CLASSh data for certain students were discarded (n = 13) if students answered the discriminator item 10 incorrectly (see item 10 Appendix E). Test question data were discarded if students made no attempt at answering either the pre- or post-question (n = 20). For the mapping task, only data from students who made no obvious attempt were excluded (n = 19). Mental effort data were discarded if students did not make a coherent response to the mental effort item (n = 23). Lastly free response data were discarded if no coherent attempt was made (n = 15).

6.2 CLASSh

The results from the CLASSh were analysed using the tool developed for analysis of the CLASS (Adams et al., 2006). The analysis tool focuses on determining the shift in respondents attitudes and beliefs between the pre- and post-survey. Shifts can either be to more expert-like attitudes, more novice-like attitudes, or there can be no significant shift. In Table 6.1, the shifts in each item of the CLASSh survey are denoted for both the computer-based and video-based multimedia tool. Within Table 6.1, items from the CLASSh are grouped into the three categories of ‘real world connection, ‘conceptual understanding and ‘applied conceptual understanding (see Section 4.2 for more details).

From Table 6.1, there are more positive shifts toward expert views in the computer-based multimedia compared to the video-based. These shifts suggests that students who used the computer tool shifted their attitudes and beliefs more toward expert-like views than their video tool counterparts.

1In addition to the 12 students from School 1, who did not participate in this
<table>
<thead>
<tr>
<th>Item</th>
<th>Computer tool</th>
<th>Video tool</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real world connections category</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning physics changes my ideas about how the world works.</td>
<td>Novice</td>
<td></td>
</tr>
<tr>
<td>Reasoning skills used to understand physics can be helpful to me in my everyday life.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The subject of physics has little relation to what I experience in the real world.</td>
<td>Expert Novice</td>
<td></td>
</tr>
<tr>
<td>To understand physics, I sometimes think about my personal experiences and relate them to the topic being analysed.</td>
<td>Expert</td>
<td></td>
</tr>
<tr>
<td><strong>Conceptual understanding category</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A significant problem in learning physics is being able to memorize all the information I need to know.</td>
<td>Expert</td>
<td></td>
</tr>
<tr>
<td>After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.</td>
<td>Expert</td>
<td></td>
</tr>
<tr>
<td>Knowledge in physics consists of many disconnected topics.</td>
<td>Expert</td>
<td></td>
</tr>
<tr>
<td>I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.</td>
<td>Novice Expert</td>
<td></td>
</tr>
<tr>
<td>If I don’t remember a particular equation needed to solve a problem on an exam, there’s nothing much I can do (legally!) to come up with it.</td>
<td>Expert Expert</td>
<td></td>
</tr>
<tr>
<td>Spending a lot of time understanding where formulas come from is a waste of time.</td>
<td>Expert</td>
<td></td>
</tr>
<tr>
<td><strong>Applied conceptual understanding category</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A significant problem in learning physics is being able to memorize all the information I need to know.</td>
<td>Expert</td>
<td></td>
</tr>
<tr>
<td>After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.</td>
<td>Expert</td>
<td></td>
</tr>
<tr>
<td>Knowledge in physics consists of many disconnected topics.</td>
<td>Expert</td>
<td></td>
</tr>
<tr>
<td>When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.</td>
<td>Expert</td>
<td></td>
</tr>
<tr>
<td>If I don’t remember a particular equation needed to solve a problem on an exam, there’s nothing much I can do (legally!) to come up with it.</td>
<td>Expert Expert</td>
<td></td>
</tr>
<tr>
<td>If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.</td>
<td>Expert Expert</td>
<td></td>
</tr>
<tr>
<td>If I get stuck on a physics problem, there is no chance I’ll figure it out on my own.</td>
<td>Novice</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.1: Shifts between pre- and post-CLASSh items (blank spaces indicates no significant change).
If the survey responses are plotted by category rather than per item (see Figure 6.1), we can see that both the computer and video tool are successful in promoting more expert-like views in students. However, from Figure 6.1, the shifts from the computer tool are consistently larger than those for the video tool. With regards to the ‘real world connections’ category, the effects of the video tool vary greatly in comparison to the computer tool, seeming to push students towards more novice attitudes and beliefs. The data from Figure 6.1 agrees with Table 6.1, strengthening the argument for larger efficacy of the computer tool in shifting students to more expert-like attitudes and beliefs.

From Figure 6.1, it is also worth noting that the students from both the computer and video tool groups have roughly the same pre-survey attitudes and beliefs, in terms of the percentage of expert vs novice responses. Additionally, students in both groups distinctly have more expert views in the ‘real world connection’ category and more novice views in the ‘applied conceptual understanding’ category.

Figure 6.1: Total shifts between pre-(blue) and post-(red) survey by category for each multimedia tool.
6.3 Test question

The pre- and post-test question were marked according to marking criteria (see Appendix H), with a maximum mark of 4. There was a statistically significant difference between the pre- and post-test marks for both computer and video tools, meaning students achieved genuine gains from the pre- to the post-test (see Appendix K for more details). Gains were calculated for each student for the two tools and the distribution of gains between the pre- and post-question is shown in Figure 6.2.

![Gain distribution for computer tool and video tool](image)

Figure 6.2: Gain distributions for the computer tool (left) and video tool (right).

Analysis found that neither distribution could be considered normal (Gaussian) (computer tool ($W = 0.896, p < 0.001$), video tool ($W = 0.911, p = 0.005$)). The computer tool ($n = 55$) saw a mean gain of 0.47 ($SD = 0.67$) from the pre- to the post-question. Comparatively, the video tool ($n = 38$) yielded a mean gain of 0.59 ($SD = 0.68$). A Mann-Whitney test showed no statistically significant difference in the gains between the computer and video tool ($U = 954, Z = 0.737, N = 93, p = 0.46$, two-tailed). Therefore, both the computer and video tool were as effective as each other in increasing students ability to answer the test question posed.

6.4 Student mapping task

The pre- and post-mapping was analysed for complexity using a modification of Fletchers (2004) categorisation (discussed in Section 4.3, see Appendix L). The focus of this analysis was to examine how the computer and video tools affected the way students represented their ‘motor effect’ knowledge structure. Figure 6.3 is an example of how a student’s way of representing knowledge changes from before to after use of the (in this case video) multimedia tool.

![Example of student’s pre-(left) and post-(right) maps](image)

Figure 6.3: Example of a student’s pre-(left) and post-(right) maps.

The distribution of pre- and post-map types for the two tools are shown in Figure 6.4, ordered by
complexity. From Figure 6.4, it is evident that both multimedia tools are successful in shifting students’ representation of their knowledge structures to a higher complexity. A Mann-Whitney test shows there is no statistically significant difference between the distribution of the post map types of students using either the computer or video tool ($U = 664, Z = -1.1613, N = 82, p = 0.107$, two-tailed). Hence, both tools are equally successful in positively altering students’ way of representing their knowledge.

Figure 6.4: Shift in students pre- and post-maps for the multimedia tools (note that more complex map types lie to the right).

### 6.5 Mental effort

An analysis of the students’ ratings of mental effort for the two tools is shown in Table 6.2. A Mann-Whitney test showed a statistically significant difference between the mental effort for students using each tool ($U = 500, Z = -2.622, N = 78, p = 0.009$, two-tailed). Thus, higher mental effort is reported by students using the video tool. It is also worth noting that the mean mental effort reported from both tools was not high (out of the 9-point Likert scale), indicating that students were not cognitively overloaded.
### Table 6.2: Mental effort data.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Mean</th>
<th>SD</th>
<th>SEM</th>
<th>Normality test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer</td>
<td>4.03</td>
<td>1.69</td>
<td>0.28</td>
<td>Not normal ($p = 0.002$)</td>
</tr>
<tr>
<td>Video</td>
<td>5.20</td>
<td>2.05</td>
<td>0.32</td>
<td>Not normal ($p = 0.050$)</td>
</tr>
</tbody>
</table>

### 6.6 Student feedback

An analysis of the feedback from the free response items is shown in Table 6.3.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Positive</th>
<th>Negative</th>
<th>Neutral</th>
<th>Did not respond</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer</td>
<td>53</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>62</td>
</tr>
<tr>
<td>Video</td>
<td>41</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>47</td>
</tr>
</tbody>
</table>

Table 6.3: Breakdown of free response types.

From these results, it is evident that students almost uniformly rate both multimedia tools positively. This confirms the development of the tools has been successful in creating something of perceived value to students. A Chi-squared test (with Yates correction for small bin totals) shows no significant difference between the two multimedia tools ($\chi^2(2, N = 109) = 2.124, p = 0.574$), suggesting that students do not prefer one tool over the other.

A more detailed NVivo analysis examined the number of responses which used specific key words positively (see Table 6.4). Again there are similarities between the computer and video tool, but, perhaps as expected, the computer tool had comments on ‘interactivity’ whereas the video tool did not.

<table>
<thead>
<tr>
<th>Key word(s)</th>
<th>Computer tool ($n = 62$)</th>
<th>Video tool ($n = 47$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Revis*</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Help*</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>Link*, connect* or relate</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Eas* (i.e. easy)</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Interest* or engag*</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Interactiv*</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 6.4: NVivo analysis (* denotes a fuzzy search term, for example ‘Revis*’ would include revision, revise or revising).

### 6.7 Teacher feedback

All teachers who provided feedback (full teacher responses can be found in Appendix M) were positive about the use of link maps to aid students learning, identifying that their students struggled to organise knowledge into coherent structures. Teachers also agreed that the link map multimedia tool that they were exposed to would be useful in revising the content in the HSC syllabus.
Chapter 7

Discussion

7.1 Answering the research questions

7.1.1 Can link maps be successfully integrated into computer-based and video-based multimedia tools for high school physics?

In answering this research question, the focus was on the high school physics classroom, and how each multimedia format could be used considering its inherent native features. This meant that, while the way each multimedia was used was different, the actual link mapping and the manner it was embedded in the multimedia followed research based principles (Mayer, 2005). Both tools were successfully deployed while maintaining the integrity of the link map concept used in earlier studies (Lindstrøm & Sharma, 2009), and being mindful of cognitive load theory (Sweller et al., 1998). Therefore, the novel approach of integrating all of the research fields discussed in Chapter 2 was successful.

Evidence from the open-ended responses from students suggests that both the computer and video tools are effective from the student perspective (see Table 6.3). This is a necessary first step in evaluating the pedagogical validity of the multimedia tools that were developed. Without student engagement, any beneficial effects will be stifled by the hurdle of student disinterest. On this same issue, teacher evaluation of any multimedia tool will be the deciding factor of whether such a tool will be implemented at all. The positive responses of the teachers suggest that multimedia tools based on link maps would be taken up by teachers to use in their classrooms, particularly in revision.

Another important factor in the evaluation of the tools is how feasible they are to implement into the high school context. This was a key consideration of the design of the multimedia tools. There were no issues with student access to either of the multimedia tools in any of the schools visited during the research project, suggesting that the developed tools can be integrated into the infrastructure available in many (if not all) schools. Therefore, the evidence gathered within this research project suggests that link maps can be successfully integrated into both types of multimedia to teach high school physics. With this critical hurdle cleared, assessment of the effect on students are worthwhile.

7.1.2 How do the link map tools influence students’ attitudes and beliefs about physics?

Results from the CLASSh, show that students started with similar beliefs and attitudes (see Figure 6.1). Specifically, it was shown that students in the study varied in their expertise of different categories related to their attitudes and beliefs — having more expert-like beliefs for the ‘real world connection’ category, while having significantly more novice-like beliefs for the ‘applied conceptual connection’ category. This raises interesting and valuable points about learning physics at the high school level. Firstly, the lower number of ‘expert’ student responses to the ‘applied conceptual understanding’ category reflects the novice status of the student participants, whose limited experience in physics materialises in a limited ability to use the knowledge they posses to solve problems. A higher number of ‘expert’ responses in the ‘conceptual understanding’ category reflects the novices progress through understanding the material before being able to apply it to various situations, with some not yet reaching that next stage. Interestingly, the ‘real world connection’ category scores are highest of all the categories for both sets of students. The problem of real world connection has been addressed specifically in the NSW HSC syl-
labus (NSW Board of Studies, 2010), with emphasis put on making the connections between the physics content learnt and its real world connections. From the CLASSh results, this effort to make such connections emerges in students’ attitudes and beliefs, an encouraging outcome. Perhaps the effort needs to be made in the syllabus to emphasise the application of conceptual understanding.

Considering how the different link map tools affected students attitudes and beliefs, the CLASSh results show a discrepancy between the two tools. The computer-based tool seemed to more positively influence students’ beliefs and attitudes than the video tool, with the largest discrepancy between the two tools in the ‘real world connection’ category. The shift towards more novice attitudes and beliefs for video-tool students, in the ‘real world connections’ category, was reflected not only in the collated CLASSh results, but in each subset (school) data set. This result is quite puzzling, as neither of the tools directly addresses the issue of real world connection. As such, there seems to be something inherent to the computer tool (perhaps the type of interactivity or scaffolding) which seems to address this point more strongly than in the video tool. Another difference between the two tools was in the difference in the ‘applied conceptual understanding’ category of the CLASSh. This result suggests that there is something about the computer tool that allows more influence over changing students views and beliefs about this category. One possible reason is the ability for the interactive computer tool to provide more expert feedback. Comparatively, with the video tool students physically created link maps in small groups — in which students who already did not have particularly ‘expert’ views and beliefs on ‘applied conceptual understanding’, would not emphasise this particular component of the link map tool.

Overall, the results from CLASSh demonstrate that (with a discrepancy on certain categories) the two multimedia tools are capable of shifting students' attitudes and beliefs about physics towards more expert-like views. Although, such a shift was only directly observed as a short term effect, the fact that such a shift took place at all is significant — especially when considering the time span in which students’ attitudes and beliefs about physics are formed. Whether this shift is maintained was beyond the scope of this study and needs to be further researched.

7.1.3 How do the link map tools influence students’ achievement on test questions?

The results from the pre- and post- test question show that both multimedia tools have a positive, statistically significant influence on students’ achievement. It is important to stress that these are gains from a revision standpoint — students have already learned the content and practised answering similar questions. In this light, the gains from the multimedia tools are not a result of just simply teaching students content. Rather, the study suggests that the gains arise out of a more coherent understanding of the physics topic due to assimilation and accretion arising from the link map tools.

No statistically significant difference exists between the gains from the two multimedia tools. This is an interesting result, demonstrating that the two different mediums in which the link map were embedded were equally effective in aiding an increase in student achievement on test questions.

7.1.4 How do the link map tools influence students’ representations of their knowledge structures?

From examining the pre- and post- student-composed maps, it can be inferred that students gain more complex knowledge structures from using the multimedia tools — at least in the short term. Although one cannot suggest that the mapping structures in the post-map composition will remain in the long-term, the results show that the multimedia tools have challenged and changed students’ knowledge structures in the short term. This is consistent with the findings of concept map research (Hattie, 2009; Horton et al., 1993). The significance of this links to the whole notion of trying to move novices towards becoming more expert. By challenging students to increase the complexity and cohesiveness of their knowledge structures, the multimedia tools take further steps in helping novices become more expert-like.

As with the test questions, the mapping data shows no significant difference between the complexity of student post-maps between the two multimedia tools. Again, this suggests that both tools are as effective as each other at conveying the link map message regarding ‘expert’ knowledge structures.
7.1.5 A note on mental effort

One of the key goals in developing the multimedia tool was the reduction of cognitive load to ensure that students were not overloaded. Students from both the computer and video tool groups reported medium levels of mental effort, so it is reasonable to say that this goal was achieved. Interestingly however, students using the video-based multimedia expressed a higher mental effort. Considering the literature, this result can be explained by the ‘self-pacing’ multimedia principle (Mayer, 2009), in that the video tool is not controlled by the student, requiring greater attentiveness throughout the duration of the video slices — leading to a higher cognitive load then the student-controlled computer tool. With no difference in post-test scores when higher mental effort is reported, this suggests that the video tool encompasses a greater amount of ‘irrelevant’ load.

It is worth noting that too little cognitive load is not particularly beneficial, as it could mean that not all the available cognitive processing is being utilised. Regardless, the benefits discussed above suggest that the cognitive processing that is being engaged is beneficial for learning.

7.2 Implications for (high school) physics education

7.2.1 The use of link maps for physics education

This research project has shown that the beneficial effects of link maps can be translated successfully both to different learning environments (multimedia platforms) as well as to a different physics learning context (high school physics). The results presented in this research strongly support the use of link map multimedia tools in the teaching of high school physics. Overall, the link map tools developed had positive effects on students’ learning.

The link map tools developed and implemented have been shown to do three things: positively influence students’ attitudes and beliefs about physics, increase achievement, and positively change knowledge structures. However, these results are meaningless if teachers and students do not value, and want to use the multimedia tools. The data gathered for this research suggests that quite the opposite is true for the multimedia tools developed in this project. On one hand, teachers have indicated that they would use the multimedia tools in their own teaching. On the other hand, students report high engagement and valuing of both the multimedia tools. In addition, the tools were easily implemented within the current typical high-school technology infrastructure. This suggests that both tools are pedagogically sound from both a teaching and learning perspective, and can be easily implemented in high-school learning contexts.

This research project has shown that the use of link map multimedia tools should be a real consideration for the physics education community.

7.2.2 Which multimedia tool?

Of key interest was the comparison of the effects of computer-based with video-based multimedia tools. This examination was novel in this project, as comparison was made not between the two multimedia tools that had been artificially matched (in the processes and interactions within the multimedia), but rather between two tools that maintained their own native features. This has shed a new perspective on the traditional ‘medium is the message’ multimedia debate (R.E. Clark 1994; Kozma, 1994).

Overall, there seems to be no significant difference between the positive effects of both the tools when utilising their native features. On measures of achievement and knowledge structure, there is no statistically significant difference between the computer-based and video-based tool. There is however, a slight discrepancy in terms of how the different tools affected students’ attitudes and beliefs, with the computer tools producing more favourable responses than the video tool. This result provides impetus for further investigation, but generally both the computer and video tools shifted students’ towards more expert attitudes and beliefs.

It is reasonable to conclude that the computer-based and the video-based tool are roughly as effective as each other in their positive effects on students. This provides an answer to the ‘multimedia debate’ —
computers or videos? From the results of this project, neither shows a distinct advantage in effects on students. Therefore, the argument could be made that for link map multimedia, the more cost and time effective tool should be favoured by future developers. The development process within this research project saw the video-based tool as the much more cost and time effective of the two, by a time-effective factor of about 10. The cost effectiveness will vary depending on the equipment and expertise available, but for this project the video tool required limited resources to complete, while the computer tool required extensive resources. It can hence be surmised that for future link map multimedia tools, utilising the video medium would provide similar outcomes to the computer-based tool for a much higher time and cost effectiveness.

7.3 A note on methodological issues

There are a number of methodological issues pertinent to educational research that are important to discuss. One is the fact that the data collected is only gauging short term effects, before and after the use of the multimedia tools. This methodology has been used in previous studies to evaluate the effectiveness of instructional tools (such as Mayo et al., 2008; Muller et al., 2008), but nonetheless, it needs to be made explicit that the results discussed in this project are short-term ones. Another feature of educational research lies in the use of surveys such as CLASSh, which aim to evaluate students’ attitudes and beliefs. Although items may have been statistically validated, analysis relies on students noting what they actually think and feel, rather than what they think the researcher might want them to think or feel. Lastly, the ‘Hawthorne effect’ is a common feature of educational research studies; where subjects improve or modify their behaviour or responses being measured, in response to the fact that they are being studied.

With all these considered, it is important to note that it is difficult for a physicist to reconcile the seemingly large numbers of uncontrollable variables. However, these are inherent to this type of educational research, and it is impossible to do any research which would exclude them all. From a physics standpoint one can draw the loose analogy with such uncontrollable variation as ‘quantum noise’. In this project, the effect of such ‘noise’ has been minimised by the triangulation of results from various data sources in a range of measurements, as well as through the explicit integration of educational theory and research in an authentic learning environment.

7.4 Further research

The time constraints of this project have meant that only the short term effectiveness of the link map multimedia tools could be measured. Therefore future research should examine the longer term effects of using link map multimedia tools on students achievement, knowledge structure, attitudes and beliefs. With additional time and resources, it would be also interesting to compare the gains from using the multimedia tool, to an equivalent duration of a classroom-style link map lesson or more traditional instruction. It is possible that the link mapping lessons would provide somewhat similar results, but it would be an important step to add the ‘control’ of traditional instruction. However, difficulties might arise in the ethics process, as well as finding teacher and student participants.

Potential research into the mental effort reported by students engaging in the multimedia tools could also be further investigated. Additionally, the interesting results of this study’s high school students’ attitudes and beliefs represent a very interesting, important, but untapped field of research.

Perhaps the biggest step for further research is the development of link map tools for other physics topic areas and perhaps even other science subject areas. This research has demonstrated the success of the first tentative step outside the specific context in which link maps have first been successful. All groups require a start, and hopefully this research has provided the impetus for building more research into the area of link map learning.
Chapter 8

Conclusion

This research has explored a novel area, integrating link maps in multimedia, in a high school physics context. Despite being the first tentative investigation into the field, the results have been exceptional. The synthesis of link maps, concept maps, cognitive load theory and multimedia learning theory to develop an effective Year 12 Physics revision tool was successful from both students’ and teachers’ perspectives. Additionally, results show that there is little difference between the effects of each tool on student attitudes and beliefs, achievement, and knowledge structures. This provides a very real consideration for future implementations of link map multimedia tools, especially in light of the considerable resource requirement when developing computer-based multimedia.

Research findings have also uncovered interesting things about the attitudes and beliefs of high school students — suggesting the importance of further research into secondary physics students (especially senior-secondary students), who remain under-represented in the research literature. In conclusion, we can answer the research questions:

1. *Can link maps be successfully integrated into computer-based and video-based multimedia tools for high school physics education?* Yes.

2. *How do link map based multimedia affect students’ attitudes, achievement and knowledge structure?* Both multimedia tools have a positive effect on students.
References


THE MOTOR EFFECT

The Motor effect:
A current carrying conductor in a magnetic field experiences a force

\[ F = Bll \sin \theta \]

Torque (\( \tau \)):
The tendency for a force to rotate an object

\[ \tau = Fd \perp \]

The torque in a coil is proportional to current, this allows us to make current measurements

To obtain torque in one direction, the current through the coil has to be reversed every half cycle using a split ring commutator

The use of an alternating current power supply can provide an alternating 'back and forth' force on a coil

The Right Hand Palm/Push Rule
Using your right hand, if you align your fingers to the direction of the magnetic field and your thumb to the direction of positive charge movement (current), then your palm will face the direction of the force

DC motors

Galvanometers

Loudspeakers
**ELECTROMAGNETIC INDUCTION**

**Faraday's Law:**
When a conductor experiences a change in magnetic flux, an emf will be induced.

\[ \mathcal{E} = -n \frac{\Delta \phi}{\Delta t} \]

**Lenz's Law:**
The direction of the emf or induced current is such that it opposes the change in magnetic flux that caused it.

**Eddy Currents:**
Closed, circular loops or current with a direction given by Lenz's Law.

**Induced current**

**Magnetic Flux:**
The number of field lines passing through an area.
\[ \phi = BA \]

**Conservation of energy:**
Energy can neither be created or destroyed. Lenz's Law leads to a resistive force and hence requires work to be done which is then converted into electrical energy.

**Back emf**
An emf induced in motors that oppose the supply emf.

**DC MOTORS**
Reduces speed. Limits current in the coil.

**Induction cooktops**
Changing magnetic fields provided by AC current in a coil can induce eddy current in metal cookware - heating them up.

**Electromagnetic braking**
Moving parts such as wheels are placed in a magnetic field, inducing eddy currents within them, and by Lenz’s law acting to slow it down.

**Generators**
When a moving coil is placed within a magnetic field, AC or DC current is generated depending on the use of slip rings or a commutator. The setup of the simple generator is very similar to that of the DC motor.
SPECIAL RELATIVITY

1. Speed of light is constant. In a vacuum:
   \[ c = 3 \times 10^8 \text{ m/s} \]

2. The principle of relativity holds for all inertial frames of reference

Galilean relativity
Observers in an inertial frame of reference cannot do any mechanical experiment to determine whether they are stationary or moving at constant velocity

Inertial frames of reference
A frame of reference in which Newton’s laws hold (non-accelerating)

Non–inertial frames of reference
A frame of reference in which Newton’s laws do not hold (accelerating)

Consequences

Time dilation
Moving clocks tick slower, time slows down for moving objects

\[ t_v = \frac{t_o}{\sqrt{1 - \frac{v^2}{c^2}}} \]

Length contraction
Moving lengths appear shorter along the direction of motion

\[ l_v = l_o \sqrt{1 - \frac{v^2}{c^2}} \]

Mass dilation
Moving masses see an increase in mass as the approach c

\[ m_v = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}} \]

Relativity of simultaneity
Events which are simultaneous for one observer aren’t necessarily so for others

Equivalence of mass and energy
Approaching the speed of light, the energy put into increasing an object’s speed transforms to increasing the mass of the object. Energy can be converted to mass and vice versa

\[ E = mc^2 \]

Aether model
The ‘aether’ was the medium through which light waves propagated

Michelson Morley Experiment
Attempted to find evidence for the aether model by comparing the speed of light beams travelling with or against the aether wind. No difference in speed was observed, a ‘null result’, neither proving or disproving the existence of the aether

Why?

Atomic clocks
An identical atomic clock placed on a clock flying around the earth elapses less time than one that remains on the surface.

Muons
Created in the upper atmospheres, their observation at the Earth’s surface is only possible by their great speed leading to time and length dilation.
**Key**

- **TOPIC TITLE**

  - **Concept directly related**

  - **Important equation**

  - **This colour signifies a vital law, idea concept**

  - **Purple and purple dots signify a concept from another link map**

  - **Real world practical applications or examples**

- **Important idea not directly linked**

- **Related knowledge**
<table>
<thead>
<tr>
<th>Slide/Screen</th>
<th>Action</th>
<th>Description</th>
<th>Audio Track</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1</td>
<td>- [Text: “Welcome”] appears on screen. Audio then plays. Scrolling text [A] on screen in time with audio.</td>
<td>1a</td>
</tr>
<tr>
<td>1</td>
<td>1.2</td>
<td>- [Text: “Welcome”] fades out and is replaced by [Text: “Instructions”] in the same place. - Audio plays. Scrolling text [B] on screen in time with audio. - Show {Continue} and {Replay} buttons.</td>
<td>1b</td>
</tr>
<tr>
<td>1</td>
<td>1.3</td>
<td>- Audio plays. - Activate both {Continue} and {Replay} buttons.</td>
<td>1c</td>
</tr>
<tr>
<td>2 (refer to key, last slide to identify boxes)</td>
<td>2.2</td>
<td>- [Text: “Getting started”] only on screen, centred. - Audio plays.</td>
<td>2a</td>
</tr>
<tr>
<td>2</td>
<td>2.3</td>
<td>- [Text: “Getting started”] moves from centre position to top title position. - Wash-out effect, rest of screen somewhat white and transparent. - [‘Directly related concept box’] appears centred. - Audio plays. - [‘Directly related concept box’] moves to final position.</td>
<td>2b</td>
</tr>
<tr>
<td>2</td>
<td>2.4</td>
<td>- Wash-out effect, rest of screen somewhat white and transparent. - [‘Important equation’ box] appears centred. - Audio plays. - [‘Important equation’ box] moves to final position.</td>
<td>2c</td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>- Wash-out effect, rest of screen somewhat white and transparent. - [Orange writing] appears centred. - Audio plays. - [Orange writing] moves to final position.</td>
<td>2d</td>
</tr>
<tr>
<td>2</td>
<td>2.6</td>
<td>- Wash-out effect, rest of screen somewhat white and transparent. - [‘Real world examples’ box] appears centred. - Audio plays. - [‘Real world examples’ box] moves to final position.</td>
<td>2e</td>
</tr>
<tr>
<td>2</td>
<td>2.7</td>
<td>- [‘Related knowledge’ cloud] appears centred. - Audio plays. - [‘Related knowledge’ cloud] moves to final position.</td>
<td>2f</td>
</tr>
<tr>
<td>2</td>
<td>2.8</td>
<td>- Audio plays. - Show {Key} button at the top right of screen. Make {Key} pulsate. - Activate both {Continue} and {Replay} buttons. - Make {Continue} pulsate.</td>
<td>2g</td>
</tr>
<tr>
<td>3</td>
<td>3.1</td>
<td>- [Text: “An example of Map structure”] appears on screen. - Audio plays. - [Text: “The common cold appears”] below heading while the last bit of the audio plays (specifically when ..”we will examine is the common cold”). - [‘Next’ button] appears.</td>
<td>3a</td>
</tr>
<tr>
<td>3</td>
<td>3.2</td>
<td>- Audio plays. - [‘Immune system’ box] and [‘Cold virus’ box] appear. - Links between the boxes and the instructions appear.</td>
<td>3b</td>
</tr>
<tr>
<td>3</td>
<td>3.3</td>
<td>- Audio plays. - [‘Germ theory’ box appears] linked to [‘Cold virus’ box].</td>
<td>3c</td>
</tr>
<tr>
<td>3</td>
<td>3.4</td>
<td>- Audio plays.</td>
<td>3d</td>
</tr>
</tbody>
</table>
- ['Equation’ box] appears, with links to ['Cold virus’ box] and ['Germ theory’ box] halfway through audio playing

| 3.5 | - Audio plays  
- ['Medicines’ box] appears and is linked to ['Germ theory’ box] halfway through audio playing | 3e |
| 3.6 | - Audio plays  
- ['Attacks’ link] appears between ['Immune system’ box] and ['Cold virus box’] | 3f |
| 3.7 | - Audio plays  
- ['Symptoms’ link] appears  
- Horizontal line, then vertical link and ['Fever’ box ] appears, then link and ['Sore throat’ box] then link and ['Runny nose’ box] appears. These occur rather quickly after each other and while the audio is about halfway through. | 3g |
| 3.8 | - Audio plays  
- ['Treatment’ link] appears, just as audio finishes. | 3h |
| 3.9 | - Audio plays  
- [Reveal {Key} button, {Replay} button and {Continue} button | 3i |

| 4 | - [Heading Text: “Arranging a Link Map”] only thing on screen  
- Audio plays, rest of page appears | 4a |
| 4.1 | - Audio plays  
- {Check all} button appears on screen and is active | 4b |
| 4.2 | - Audio plays  
- {Check all} button appears on screen and is active | 4c |

| 5 | - Transition from the completed map in the previous screen with a 'wipe' effect so that it now covers the ‘click and drag’ section of the previous screen.  
- If possible, extend the ‘wipe’ effect to ‘white-out’ the previous heading. If not just remove the previous heading (perhaps ‘dissolve’ away)  
- Fade in heading ['Click to find out more information about each part of the link map']  
- Audio plays | 5a |
| 5.1 | - Audio plays  
- Timer 2 minutes before {Continue} button is activated.  
- Activate {Continue} button | 5b |
| 5.2 | - Click [The Motor effect] box  
- then Audio plays, rest of map ‘fades/ whites out’, except the two links attached to the box | 5i |
| 5.3.i | - Click [The Right Hand Palm/Push Rule] box  
- then Audio plays, rest of map ‘fades/ whites out’, except the link attached to the box | 5ii |
| 5.3.ii | - Click [F=BIL sin(theta)] box  
- Then Audio plays, rest of map ‘fades/ whites out’, except the ‘magnitude of force’ link attached to the box. | 5iii |
| 5.3.iv | - Click [torque] box  
- then Audio plays, rest of map ‘fades/whites out’, except the link attached to the box (in this case there is no link – the cloud box intrinsically has a ‘link’ itself) | 5iv |
| 5.3.v | - Click [torque equation] box  
- then Audio plays, rest of map ‘fades/whites out’, except the links attached to the box | 5v |
| 5.3.vi | - Click [text: ‘torque on a current carrying coil…] box  
- then Audio plays, rest of map ‘fades/whites out’, except the links attached to the box (from two equations above it – NOT the equation below it) | 5vi |
| 5.3.vii | - Click [torque = nBIA equation] box  
- then Audio plays, rest of map ‘fades/whites out’, except the links attached to the box | 5vii |
| 5.3.viii | - Click [text: ‘To obtain torque in one direction…’] box  
- then Audio plays, rest of map ‘fades/whites out’, except the links attached to the box | 5viii |
| 5.3.ix | - Click [DC motors] box  
- then Audio plays, rest of map ‘fades/whites out’, except the links attached to the box | 5ix |
| 5.3.x | - Click [text: ‘The torque in a coil is proportional…’] box  
- then Audio plays, rest of map ‘fades/whites out’, except the links attached to the box | 5x |
| 5.3.xi | - Click [Galvanometers] box  
- then Audio plays, rest of map ‘fades/whites out’, except the links attached to the box | 5xi |
| 5.3.xii | - Click [text: ‘The use of an alternating current power supply..’] box  
- then Audio plays, rest of map ‘fades/whites out’, except the links attached to the box | 5xii |
| 5.3.xiii | - Click [torque equation] box  
- then Audio plays, rest of map ‘fades/whites out’, except the links attached to the box | 5xiii |
| 6 | 6.1 | - [Heading Text: “Arranging a Link Map”] only thing on screen  
- Audio plays, rest of page appears | 6a |
| 6.2 | - Audio plays  
- {Check all} button appears on screen and is active | 6b |
| 6.3 | - Audio plays  
{Check all}  
- Checks the position of all the components. Ticks the components that are in the right spot and moves those which are not back to the ‘click and drag’ box.  
- If all correct text in {Check all} button turn to ‘Correct!’ and {Continue} button visible and active | 6c |
| 7 | 7.1 | - [Heading Text: ‘Completed Map’] and completed Link Map on page  
- Audio plays | 7a then 7b |
| 8 | 8.1 | - [Text: “Summary”] appears on screen. Audio then plays. Scrolling text [C] on screen in time with audio. | 8a |
| 8.2 | - Audio plays. Scrolling text [D] on screen in time with audio | 8b |
| 8.3 | - [Text: “Summary”] fades out and is replaced by [Text: “Thank you”] in the same place.  
- Audio plays. Scrolling text [E] on screen in time with audio  
- Show {Replay} buttons.  
{Replay}  
- Go to start | 8c |
Other notes

- Only activate {Continue} and {Replay} buttons after processes finish.
- ‘Key’ button to take student back to key
- PowerPoint is a bit sloppy – feel free to add your uniformity to headings etc.
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<tr>
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<th>Script</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1a</td>
<td>“Welcome. This computer program will take you through the construction of a ‘Link Map’ on the Motor Effect. ‘Link Maps’ are graphical representations of the relationships between various Physics concepts, and are similar to concept maps.”</td>
</tr>
<tr>
<td></td>
<td>1b</td>
<td>“Each screen will guide your actions. At the bottom right of each screen is a continue button to go to the next screen. On some screens, there is also a ‘replay’ button, which will allow you to replay the information provided on that screen.”</td>
</tr>
<tr>
<td></td>
<td>1c</td>
<td>“Press continue when you are ready to proceed.”</td>
</tr>
<tr>
<td>2</td>
<td>2a</td>
<td>“An integral part of Link Maps is the ‘structure’ that represents the ideas. We will now briefly outline the different ‘shapes and colours’ which all hold distinct meanings.”</td>
</tr>
<tr>
<td></td>
<td>2b</td>
<td>“This ‘blue’ box, represents a concept that is directly related to whatever it is linked to”</td>
</tr>
<tr>
<td></td>
<td>2c</td>
<td>“This yellow box, indicates an important and relevant equation”</td>
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<td></td>
<td>2d</td>
<td>“This ‘orange’ colour, signifies an important law, idea or concept”</td>
</tr>
<tr>
<td></td>
<td>2e</td>
<td>“Real world applications or examples are shown in this ‘black’ box with ‘green’, underlined, text”</td>
</tr>
<tr>
<td></td>
<td>2f</td>
<td>“Finally, this ‘cloud’ shape represents related physics knowledge”</td>
</tr>
<tr>
<td></td>
<td>2g</td>
<td>“There will be a light blue ‘key’ button at the top right of screen that will take you back to this information whenever you need to. Press continue to move on to looking at an example of the structure of a Link Map”</td>
</tr>
<tr>
<td>3</td>
<td>3a</td>
<td>“We will now look at an example to familiarise ourselves with how Link Maps work. The example we will examine is the common cold. Keep in mind that this is just an example, so it is not important to know the content completely. When you are ready, clicking the ‘Next’ button at the bottom right of the screen will take you through the example.”</td>
</tr>
<tr>
<td></td>
<td>3b</td>
<td>“Two directly related concepts to the common cold - are the ‘Immune system’ and the ‘Cold virus’. As such, they are connected to ‘The common cold’ in blue boxes. Since they are also vital ideas, they are in ‘orange’ text.”</td>
</tr>
<tr>
<td></td>
<td>3c</td>
<td>“The ‘Cold virus’ concept is underpinned by ‘Germ Theory’, so this appears as a cloud-shaped box, linked to the ‘Cold virus’. The vital concept of ‘Germ theory’ is shown in ‘orange’ text.”</td>
</tr>
<tr>
<td></td>
<td>3d</td>
<td>“Germ theory outlines the growth of viruses, which can be approximated by an equation. This equation will be in a yellow box and linked to both ‘Germ theory and ‘Cold virus’ boxes.’”</td>
</tr>
<tr>
<td></td>
<td>3e</td>
<td>“Additionally, ‘Germ theory’ has a very useful real-world application, which is in informing the creation and development of medicines. Therefore, medicine is in a black ‘application’ box in green underlined text, and is linked to ‘Germ theory’.”</td>
</tr>
<tr>
<td></td>
<td>3f</td>
<td>“There is a link between ‘Immune system’ and ‘Cold Virus’ concepts – because the immune system ‘attacks’ the Cold virus.”</td>
</tr>
<tr>
<td></td>
<td>3g</td>
<td>“This ‘attacking’ link actually leads to the common cold ‘symptoms’, such as ‘fever’, ‘sore throat’ and ‘runny nose’, so these ‘symptoms’ are connected to the ‘attacks’ link. These symptoms are ‘real-world’ examples - so they are found in black boxes, in green underlined text.”</td>
</tr>
</tbody>
</table>
Finally, we know that there are medicines which help treat the symptoms of the common cold, so we also have a ‘treatment’ link coming from the ‘medicine’ box to the ‘symptoms’.

This example has introduced you to what ‘Link Maps’ are all about. Take the time to have a look at the components and overall structure. Feel free to go to the ‘key’, using the button on the top right of your screen. Click ‘continue’ if you are confident with the general structure of ‘Link Maps’, or hit ‘replay’ to see the example again.

We will now look at ‘arranging’ a Link Map for the ‘motor effect’. On the right of this screen, are components which you need to click and drag onto the Link Map to where you think they fit

When you have dragged all the components into place, click on the ‘check all’ button to check your answers. When all the components are correctly placed, click ‘Continue’ to take you to the next screen

Don’t let the number of parts in the map overwhelm you, work through the map part by part – I suggest starting from the heading

On your completed Map, you can ‘click’ the components of the map to hear some information about the component and how it fits into the overall Link Map.

You will have at least 2 minutes to do this. After this time, a ‘continue’ button will appear that will take you to the next screen, click on it when you are ready to proceed

The motor effect is a concept, which describes the phenomenon that, when a current carrying conductor is in a magnetic field, it will experience a force. This concept links to parts of the link map which describe the direction of the force and the force’s magnitude

The right hand palm or push rule, is linked to the motor effect, as it describes the direction of the Motor effect force. Essentially it states that: ‘Using your right hand, if you align your fingers to the direction of the magnetic field, and your thumb to the direction of positive charge movement (current), then your palm will face the direction of the force.’

The magnitude of the motor effect force is given by the equation $F = BIL \sin \theta$. Therefore this equation is linked to the motor effect concept. The equation states, that the force on a straight, current carrying conductor in a magnetic field, is equal to the product of the magnitude of the magnetic field (B), the current flowing through the coil (I), the length of the conductor (l) and the sin of the angle (theta) between the length of the conductor and the magnetic field.

A piece of related physics knowledge to the motor effect is the idea of ‘torque’. Torque is the tendency for a force to rotate an object, about an axis.

The equation for torque, states that torque ($\tau$), is equal to the force applied (F) multiplied by to the perpendicular distance from the axis of rotation ($d_{\text{perp.}}$). On this link map this equation is both linked to the torque concept, as well as to how the torque equation interacts with the motor effect equation.

The concepts of the motor effect and torque come together to give us a description of the torque on a current carrying coil in a magnetic field. Therefore we see the links from this to both the equations of force and torque.

The equation for the torque on a current carrying coil in a magnetic field is given by $\tau = nBIA\cos(\theta)$. This means that the torque will be equal to the product of the number of coils (n), the magnitude of the magnetic field (B), the current in the coil (I), the area of the coil (A), and the cosine of the angle between the plane of the coil and the magnetic field (theta).

When talking about a current-carrying coil, it is useful to make the coil constantly turn in one direction. To obtain this constant torque, the current through the coil has...
to be reversed every half cycle using a ‘split ring commutator’. This is therefore linked to the concept of torque as well as where it is utilised in a practical application – in DC motors”

5ix  “DC, or ‘direct-current’ motors are a practical application of the motor effect, and the use of a split ring commutator provides a constant torque and rotation in one direction”

5x  “The torque on a coil is proportional to the current flowing through it, and this allows us to make current measurements through the measurement of torque. This idea is linked to the concept of torque, but also to how it is used in a practical sense – in current measuring devices called ‘galvanometers’.”

5xi  “Galvanometers are devices which measure current. They operate on the principle of relating the torque on a coil to the current passing through it, and are hence linked to this idea.”

5xii  “The use of an alternating current (AC) power supply can provide an alternating ‘back and forth’ force on a coil. This idea relates to both the mathematical expression for the magnitude of force and to the practical application of the idea – in loudspeakers.”

5xiii  “Loudspeakers produce sound through the ‘back-and-forth’ movement of a current carrying coil in a magnetic field. This coil is connected to a cone that produces the sound. This is how loudspeakers are linked to the motor effect.”

6a  “We will now look at arranging the Link Map for the Motor effect a second time. The method is the same as last time, with ‘click and drag’ components on the right of the screen.”

6b  “When you have dragged all components into place, click on the ‘check all’ button to check you answers. When all the components are in the right spot, click ‘Continue’ to take you to the next screen”

6c  “Again, don’t let the number of parts of the map overwhelm you, work through the map part by part. Again, I suggest starting from the heading”

7a  “Good job. Hopefully you are getting a good grasp of how the various concepts that you have learnt surrounding the ‘motor effect’ fit together. Link Maps aim to make the process of seeing and understanding this easier.”

7b  “Feel free to again explore the link map by clicking over components to hear how they fit into the overall Link Map. After you have finished this click ‘continue’ to take you to the final screen.”

8a  “The aim of this computer program is to help you understand how the various concepts that you have learnt surrounding the ‘motor effect’ fit together. Hopefully it has helped you do so.”

8b  “Link Maps aim to stress that Physics knowledge is all connected. Each of the various concepts and ideas you may have learnt, are related and linked to each other, and fit together in an overall structure. Therefore, Link Maps can be utilised in representing other Physics topics such as ‘special relativity’ or ‘electromagnetic induction’.”

8c  “Thanks for participating. If you wish to start again, press ‘Replay’.”
<table>
<thead>
<tr>
<th>Sequence</th>
<th>Video</th>
<th>Script</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intro</td>
<td>- Talking head&lt;br&gt;- Concept map graphic</td>
<td>- “Welcome. This video will guide you through an introduction to ‘Link Maps’”&lt;br&gt;- “Link Maps are similar to concept maps and mind maps. However they are tailored specifically to Physics.”&lt;br&gt;- “This video presentation will introduce you to how Link Maps work, and go through the composition of one about Motors and Generators.”</td>
</tr>
<tr>
<td>Key – intro</td>
<td>- Talking head</td>
<td>- “To start off, we need to introduce you to what Link Maps are. Link Maps serve as a graphical tool to help represent physics knowledge. In doing so, they help to emphasise the connections between various pieces of physics knowledge”</td>
</tr>
<tr>
<td>Key – component talk through</td>
<td>- Talking head&lt;br&gt;- Flash ups of the various boxes</td>
<td>- “As such, An integral part of Link Maps is the ‘structure’ that represents the ideas. We will now briefly outline the different ‘shapes and colours’ which all hold distinct meanings.”&lt;br&gt;- “This ‘blue’ box, represents a concept that is directly related to whatever it is linked to”&lt;br&gt;- “This yellow box, indicates an important and relevant equation”&lt;br&gt;- “This ‘orange’ colour, signifies an important law, idea or concept”&lt;br&gt;- “Real world applications or examples are shown in this ‘black’ box with ‘green’, underlined, text”&lt;br&gt;- “Finally, this ‘cloud’ shape represents related physics knowledge”</td>
</tr>
</tbody>
</table>
| Example | - Talking head  
- Composition of Map | - “We will now look at an example to familiarise ourselves with how Link Maps work. The example we will examine is the common cold. Keep in mind that this is just an example, so it is not important to know the content completely

- “Two directly related concepts to the common cold - are the ‘Immune system’ and the ‘Cold virus’. As such, they are connected to ‘The common cold’ in blue boxes. Since they are also vital ideas, they are in ‘orange’ text.”

- “The ‘Cold virus’ concept is underpinned by ‘Germ Theory’, so this appears as a cloud-shaped box, linked to the ‘Cold virus’. The vital concept of ‘Germ theory’ is shown in ‘orange’ text.

- “Germ theory outlines the growth of viruses, which can be approximated by an equation. This equation will be in a yellow box and linked to both ‘Germ theory and ‘Cold virus’ boxes.”

- “Additionally, ‘Germ theory’ has a very useful real-world application, which is in informing the creation and development of medicines. Therefore, medicine is in a black ‘application’ box in green underlined text, and is linked to ‘Germ theory’.”

- “There is a link between ‘Immune system’ and ‘Cold Virus’ concepts – because the immune system ‘attacks’ the Cold virus.”

- “This ‘attacking’ link actually leads to the common cold ‘symptoms’, such as ‘fever’, ‘sore throat’ and ‘runny nose’, so these ‘symptoms’ are connected to the ‘attacks’ link. These symptoms are ‘real-world’ examples - so they are found in black boxes, in green underlined text.”

- “Finally, we know that there are medicines which help treat the symptoms of the common cold, so we also have a ‘treatment’ link coming from the ‘medicine’ box to the ‘symptoms’.
| Instructions for Groupwork | Talking head | - “This example has introduced you to what ‘Link Maps’ are all about”
- “Now you have the opportunity to try to compose your own Link Map”
- You will receive various components of a Link Map on ‘The motor effect’. In groups try to put the map together. You will have about 5 min”

| Rounding up groupwork | Talking head | - “OK. Time is up. Please stop working on the map. You will have an opportunity to make final corrections”
- “Let’s examine what the structure of a Link Map on the Motor Effect should look like”

| Link Map guided composition | Talking head | - Graphics composing the link map
- “The right hand palm or push rule, is linked to the motor effect, as it describes the direction of the Motor effect force. Essentially it states that: ‘Using your right hand, if you align your fingers to the direction of the magnetic field, and your thumb to the direction of positive charge movement (current), then your palm will face the direction of the force.’”

- “The magnitude of the motor effect force is given by the equation \( F = BIL \sin \theta \). Therefore this equation is linked to the motor effect concept. The equation states, that the force on a straight, current carrying conductor in a magnetic field, is equal to the product of the magnitude of the magnetic field \( B \), the current flowing through the coil \( I \), the length of the conductor \( L \) and the \( \sin \) of the angle \( \theta \) between the length of the conductor and the magnetic field.”

- “A piece of related physics knowledge to the motor effect is the idea of ‘torque’. Torque is the tendency for a force to rotate an object, about an axis.

- “The equation for torque, states that torque \( \tau \), is equal to the force applied \( F \) multiplied by to the perpendicular distance from the axis of rotation \( d_{\text{perp.}} \). On this link map this equation is both linked to the torque concept, as well as to how the torque equation interacts with the motor effect equation.”

- “When talking about a current-carrying coil, it is useful to make the coil constantly turn in one direction. To obtain this constant torque, the current through the coil has to
be reversed every half cycle using a ‘split ring commutator’. This is therefore linked to the concept of torque as well as where it is utilised in a practical application – in DC motors”

- “DC, or ‘direct-current’ motors are a practical application of the motor effect, and the use of a split ring commutator provides a constant torque and rotation in one direction”

- “The torque on a coil is proportional to the current flowing through it, and this allows us to make current measurements through the measurement of torque. This idea is linked to the concept of torque, but also to how it is used in a practical sense – in current measuring devices called ‘galvanometers’.”

- “Galvanometers are devices which measure current. They operate on the principle of relating the torque on a coil to the current passing through it, and are hence linked to this idea.”

- “The use of an alternating current (AC) power supply can provide an alternating ‘back and forth’ force on a coil. This idea relates to both the mathematical expression for the magnitude of force and to the practical application of the idea – in loudspeakers.”

- “Loudspeakers produce sound through the ‘back-and-forth’ movement of a current carrying coil in a magnetic field. This coil is connected to a cone that produces the sound. This is how loudspeakers are linked to the motor effect.”

<table>
<thead>
<tr>
<th>Instructions for groupwork</th>
<th>Talking head</th>
<th>“You know have a final opportunity to revise the Link Map you composed within your groups”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final words</td>
<td>Talking head</td>
<td>“That’s all from me, I hope you gained some insight into Link Maps from this short introduction”</td>
</tr>
</tbody>
</table>
Physics attitudes and beliefs survey – Pre-test

Researcher: Nigel Kuan
School of Physics, University of Sydney
nkuan@physics.usyd.edu.au

Name: ____________________________  Gender:  Male  Female

Instructions
Below are a number of statements that may or may not describe your beliefs about learning physics. Please rate each statement by circling a number between 1 and 5, where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Choose one of the five choices that best expresses your feeling about the statement. If you do not understand a statement, leave it blank. If you understand, but have no strong opinion, choose 3.

Survey

1. A significant problem in learning physics is being able to memorize all the information I need to know.

   [ ] Strongly Disagree [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] Strongly Agree

2. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

   [ ] Strongly Disagree [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] Strongly Agree

3. Knowledge in physics consists of many disconnected topics.

   [ ] Strongly Disagree [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] Strongly Agree

4. When I solve a physics problem, I locate an equation that uses the variable given in the problem and plug in the values.

   [ ] Strongly Disagree [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] Strongly Agree

5. I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.

   [ ] Strongly Disagree [ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5 [ ] Strongly Agree
6. If I don’t remember a particular equation needed to solve a problem on an exam, there’s nothing much I can do (legally!) to come up with it.

   | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

7. If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.

   | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

8. Learning physics changes my ideas about how the world works.

   | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

9. Reasoning skills used to understand physics can be helpful to me in my everyday life.

   | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

10. We use this question to discard the survey of people who are not reading the statements. Please select agree – option 4 (not strongly agree) to preserve your answers.

    | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

11. Spending a lot of time understanding where formulas come from is a waste of time.

    | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

12. The subject of physics has little relation to what I experience in the real world.

    | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

13. To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.

    | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

14. If I get stuck on a physics problem, there is no chance I’ll figure it out on my own.

    | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |
# Concept Map Structure Types

<table>
<thead>
<tr>
<th>Map Type</th>
<th>Illustration</th>
<th>Description</th>
<th>(n) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>String</td>
<td><img src="image" alt="String" /></td>
<td>Three or more concepts are linked in a single chain</td>
<td>(1) 1%</td>
</tr>
<tr>
<td>Wheel</td>
<td><img src="image" alt="Wheel" /></td>
<td>A number of single concepts emanate from a single concept</td>
<td>(2) 3%</td>
</tr>
<tr>
<td>String with a wheel attached</td>
<td><img src="image" alt="String with a wheel attached" /></td>
<td>Four or more concepts are linked in a single chain with a wheel structure attached at one end</td>
<td>(7) 10%</td>
</tr>
<tr>
<td>Hierarchy</td>
<td><img src="image" alt="Hierarchy" /></td>
<td>Concepts are arranged in a simple tree type structure</td>
<td>(16) 24%</td>
</tr>
<tr>
<td>Complex</td>
<td><img src="image" alt="Complex" /></td>
<td>Cross-linking between the concepts to form an associative network</td>
<td>(6) 9%</td>
</tr>
<tr>
<td>Complex with a wheel attached</td>
<td><img src="image" alt="Complex with a wheel attached" /></td>
<td>An associative structure with an obvious wheel structure attached</td>
<td>(20) 30%</td>
</tr>
<tr>
<td>Wheel linked to another wheel</td>
<td><img src="image" alt="Wheel linked to another wheel" /></td>
<td>Two concepts with wheel structures which are connected by a number of joining radial links</td>
<td>(12) 18%</td>
</tr>
<tr>
<td>Bubble Loops</td>
<td><img src="image" alt="Bubble Loops" /></td>
<td>Several string structures that form closed loops</td>
<td>(2) 3%</td>
</tr>
<tr>
<td>Disjoint</td>
<td><img src="image" alt="Disjoint" /></td>
<td>The concepts are arranged into two or more separate structures</td>
<td>(3) 4%</td>
</tr>
</tbody>
</table>
Instructions
The following is a question from the 2006 New South Wales Higher School Certificate Exam.
Please answer it as best you can within the time given.

Question
The diagram shows the structure of a typical galvanometer.

Describe how the galvanometer operates as an application of the motor effect.
Thank you for your time!
Link Map Research - Pre/Post Question Marking criteria

Instructions
The following is a question from the 2006 New South Wales Higher School Certificate Exam. Please answer it as best you can within the time given.

Question
The diagram shows the structure of a typical galvanometer.

![Diagram of a galvanometer]

Describe how the galvanometer operates as an application of the motor effect. 4

Marking criteria
4 marks total

For each of the points below: 1 mark for a full answer addressing the point, half-mark for a reasonable but not full answer addressing the point.

- description of motor effect
- linkage of the motor effect to components of the galvanometer
- discussion of torque on the coil
- linkage to the purpose of the galvanometer, i.e. $I\alpha r a \delta$

H-1
Physics attitudes and beliefs survey – Post-test

Researcher: Nigel Kuan
School of Physics, University of Sydney
nkuan@physics.usyd.edu.au

Name: __________________________ Gender: Male Female

Mental effort
Firstly, on the below scale, please rate the mental effort you invested in the multimedia you have just used

| Extremely Low Mental Effort | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Extremely High Mental Effort |

Given you short experience with Link Maps, please answer the survey considering how this may or may not have influenced your views.

Instructions
Below are a number of statements that may or may not describe your beliefs about learning physics. Please rate each statement by circling a number between 1 and 5, where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Choose one of the five choices that best expresses your feeling about the statement. If you do not understand a statement, leave it blank. If you understand, but have no strong opinion, choose 3.

Survey
1. A significant problem in learning physics is being able to memorize all the information I need to know.

   | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

2. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

   | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

3. Knowledge in physics consists of many disconnected topics.

   | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |

4. When I solve a physics problem, I locate an equation that uses the variable given in the problem and plug in the values.

   | Strongly Disagree | 1 | 2 | 3 | 4 | 5 | Strongly Agree |
5. I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.

[Strongly Disagree 1 2 3 4 5 Strongly Agree]

6. If I don’t remember a particular equation needed to solve a problem on an exam, there’s nothing much I can do (legally!) to come up with it.

[Strongly Disagree 1 2 3 4 5 Strongly Agree]

7. If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.

[Strongly Disagree 1 2 3 4 5 Strongly Agree]

8. Learning physics changes my ideas about how the world works.

[Strongly Disagree 1 2 3 4 5 Strongly Agree]

9. Reasoning skills used to understand physics can be helpful to me in my everyday life.

[Strongly Disagree 1 2 3 4 5 Strongly Agree]

10. We use this question to discard the survey of people who are not reading the statements. Please select agree – option 4 (not strongly agree) to preserve your answers.

[Strongly Disagree 1 2 3 4 5 Strongly Agree]

11. Spending a lot of time understanding where formulas come from is a waste of time.

[Strongly Disagree 1 2 3 4 5 Strongly Agree]

12. The subject of physics has little relation to what I experience in the real world.

[Strongly Disagree 1 2 3 4 5 Strongly Agree]

13. To understand physics, I sometimes think about my personal experiences and relate them to the topic being analysed.

[Strongly Disagree 1 2 3 4 5 Strongly Agree]

14. If I get stuck on a physics problem, there is no chance I’ll figure it out on my own.

[Strongly Disagree 1 2 3 4 5 Strongly Agree]

**Free response**
In the space below, please write any comments (good or bad points) on how you found the Link Map tool.

Thank you for your time!
Ref: PB/PR

2 November 2009

Dr M Sharma
School of Physics
Building A28
The University of Sydney
Email: m.sharma@physics.usyd.edu.au

Dear Dr Sharma

Title: Developing multimedia tools for senior high school physics

Ref. No.: 08-2006/9413

Authorised Personnel: Dr M Sharma
Mr Derek Muller
Mr Nigel Kuan

The Human Research Ethics Committee, at its Executive Meeting held on 20 October 2009, considered and approved your request dated 15 October 2009 to modify the above protocol as follows:

- The addition of the “Link Map” to the study;
- The addition of Nigel Kuan under ‘Authorised Personnel’ on the project.

The Committee found that there were no ethical objections to the modifications and therefore recommends approval to proceed.

In addition, the Executive Committee also considered and approved your Annual Report Form. Your protocol has been renewed to 31 August 2010.

Chief Investigator / Supervisor’s responsibilities to ensure that:

(1) All serious and unexpected adverse events should be reported to the HREC as soon as possible.

J-1
(2) All unforeseen events that might affect continued ethical acceptability of the project should be reported to the HREC as soon as possible.

(3) The HREC must be notified as soon as possible of any changes to the protocol. All changes must be approved by the HREC before continuation of the research project. These include:
   - If any of the investigators change or leave the University.
   - Any changes to the Participant Information Statement and/or Consent Form.

(4) All research participants are to be provided with a Participant Information Statement and Consent Form, unless otherwise agreed by the Committee. The Participant Information Statement and Consent Form are to be on University of Sydney letterhead and include the full title of the research project and telephone contacts for the researchers, unless otherwise agreed by the Committee and the following statement must appear on the bottom of the Participant Information Statement. Any person with concerns or complaints about the conduct of a research study can contact the Deputy Manager, Ethics Administration, University of Sydney, on (02) 8627 8176 (Telephone); (02) 8627 8177 (Facsimile) or human.ethics@usyd.edu.au (Email).

(5) Copies of all signed Consent Forms must be retained and made available to the HREC on request.

(6) It is your responsibility to provide a copy of this letter to any internal/external granting agencies if requested.

(7) A report and a copy of any published material should be provided at the completion of the Project.

Yours sincerely

[Signature]

Associate Professor Philip Beale
Chairman
Human Research Ethics Committee

cc: Derek Muller, email: D.muller@physics.usyd.edu.au
    Nigel Kuan, email: nkuan@physics.usyd.edu.au

Encl: Approved Link Map
Wilcoxon Signed Rank Test Data:

This tested for statistically significant differences between the pre- and post-test scores for the computer and video tools (\( p \leq 0.05 \) denotes a statistically significant difference)

<table>
<thead>
<tr>
<th></th>
<th>Z</th>
<th>N</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer</td>
<td>-4.07</td>
<td>55</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Video</td>
<td>-4.00</td>
<td>38</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Map type</td>
<td>Illustration</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------</td>
<td>------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Disjointed</td>
<td>![Disjointed Illustration]</td>
<td>The concepts are arranged into two or more separate structures.</td>
<td></td>
</tr>
<tr>
<td>Wheel</td>
<td>![Wheel Illustration]</td>
<td>A number of single concepts emanate from a single concept.</td>
<td></td>
</tr>
<tr>
<td>Hierarchy</td>
<td>![Hierarchy Illustration]</td>
<td>Concepts are arranged in a simple tree type structure.</td>
<td></td>
</tr>
<tr>
<td>Wheel + Hierarchy</td>
<td>![Wheel + Hierarchy Illustration]</td>
<td>Wheel structure with hierarchical branches.</td>
<td></td>
</tr>
<tr>
<td>Complex</td>
<td>![Complex Illustration]</td>
<td>Cross-linking between the concepts to form an associative network.</td>
<td></td>
</tr>
<tr>
<td>Complex w/ wheel</td>
<td>![Complex w/ wheel Illustration]</td>
<td>An associative structure with an obvious wheel structure attached.</td>
<td></td>
</tr>
<tr>
<td>Link map</td>
<td>![Link map Illustration]</td>
<td>Replication of link maps: hierarchical with cross links present.</td>
<td></td>
</tr>
</tbody>
</table>
Video – Teacher 1

1. How many years experience do you have in teaching physics?

30

What is you background?

Physics degree, teaching diploma, MSc in ed management, doctorate science education. Teaching 8-12 in UK, WA and NSW, age 16-adult (TAFE and tertiary) electronic engineering in UK and WA

2. Do you think the organisation of concepts into coherent structures is a common problem or issue with your students?

yes

3. How would confident are you with teaching physics in this way?

Fine- it’s good. I’ve been using mind maps for guidance

4. Do you think that Link Maps provide a way to help students organise their knowledge?

yes

5. How effective do you think the Link Map tools your students used were? Do you think they serve better as a revisional tool, or in some other capacity?

Could be used as the unit progresses to show links immediately. Or good for revision to build up own understanding

6. Do you notice any gender differences in your students with regards to the organisation of physics schema?

Generally girls are more organised from the start, boys need guidance

7. Do you have any suggestions of how Link Maps, or the Link Map tools could be improved?

Colour/shape concept is good but perhaps unnecessarily complex to reproduce. What software do you suggest? (Inspiration is fairly generic). Group I observed took up idea but stuck to boxes.

8. Do you have any comments on the use of technology in things like the Link Map tools?

As above. Is the construct as important as the arrangement and linkage of ideas?
VIDEO – Teacher 2

1. How many years experience do you have in teaching physics? What is your background?

5. BSc Honours in Physics

2. Do you think the organisation of concepts into coherent structures is a common problem or issue with your students?

Yes, specially when they do revision.

3. How confident are you with teaching physics in this way? Or confidence in general?

I agree that Mind maps would help them to guide through the topic.

4. Do you think that Link Maps provide a way to help students organise their knowledge?

Specially when they are revising.

5. How effective do you think the Link Map tools your students used were? Do you think they serve better as a revisional tool, or in some other capacity?

Mainly as a revisional tool.

6. Do you notice any gender differences in your students with regards to the organisation of physics schema?

Not really

7. Do you have any suggestions of how Link Maps, or the Link Map tools could be improved?

Adding more pictures or cartoons.

8. Do you have any comments on the use of technology in things like the Link Map tools?

no

9. Do you have any general comments about the Link Map, or the Link Map tools that your students used?

haven't focus that much
Computer – Teacher 3

1. How many years experience do you have in teaching physics? What is your background?

5 years experience. Background - Department of Physics Macquarie University, Architectural/engineering practice, biomedical engineering

2. Do you think the organisation of concepts into coherent structures is a common problem or issue with your students?

Yes

3. How confident are you with teaching physics in this way? Or confidence in general?

Confident that link maps is a viable teaching methodology

4. Do you think that Link Maps provide a way to help students organise their knowledge?

Yes

5. How effective do you think the Link Map tools your students used were? Do you think they serve better as a revisional tool, or in some other capacity?

Link maps would be an effective revision tool, a improved mind map

6. Do you notice any gender differences in your students with regards to the organisation of physics schema?

Yes, girls are more organised but not necessarily better at Physics

7. Do you have any suggestions of how Link Maps, or the Link Map tools could be improved?

Using hyperlinks

8. Do you have any comments on the use of technology in things like the Link Map tools?

Link maps can be easily applied to activeboard technology

9. Do you have any general comments about the Link Map, or the Link Map tools that your students used?

I like the tool. The different colours clearly identify different aspects of the learning material.
Computer – Teacher 4

1. How many years experience do you have in teaching physics? What is you background?

30 yrs, BSc (Applied maths) Dip Ed

2. Do you think the organisation of concepts into coherent structures is a common problem or issue with your students

Yes

3. How would confident are you with teaching physics in this way? Or confidence in general?

I intend to integrate this method more into my teaching strategies

4. Do you think that Link Maps provide a way to help students organise their knowledge?

Yes

5. How effective do you think the Link Map tools your students used were? Do you think they serve better as a revisional tool, or in some other capacity?

(no response)

6. Do you notice any gender differences in your students with regards to the organisation of physics schema?

In general their is a greater range of ability in boys doing physics, while the girls in general are more conscientious This shows in there organisation as well.

7. Do you have any suggestions of how Link Maps, or the Link Map tools could be improved?

Using hyperlinks

8. Do you have any comments on the use of technology in things like the Link Map tools?

Students are getting more and more access to technology

9. Do you have any general comments about the Link Map, or the Link Map tools that your students used?

I think it will be very valuable