



# Embedding research principles into multimedia teaching and learning tools

Nigel Kuan, Manjula Sharma, Christine Lindstrøm and Derek Muller, School of Physics, The University of Sydney, Australia  
nkuan@physics.usyd.edu.au, sharma@physics.usyd.edu.au,

**Abstract:** Past research has shown that students with lower prior experience in a subject area benefit greatly from the use of scaffolds in their learning. In teaching first year physics students with little or no prior knowledge, a particular approach using 'link maps' has been recently undertaken by the physics education research group within the School of Physics at the University of Sydney. The steady proliferation of multimedia into teaching practice has also seen research done on the effective use of technologies such as video presentations in teaching physics at tertiary and upper-secondary level. Studies on the use of multimedia often focus on motivational aspects of technological use, as well as the related learning outcomes.

With a solid research foundation for these fields, we are interested in the synthesis of these ideas into a teaching and learning tool. Our overall research aim is to develop the fundamental ideas and research basis of link maps into the multimedia environments of video and computer simulation and investigate the effects of these tools on student achievement and motivation. In this paper, we put forth the foundation of our research, in describing how previous scholarly findings inform the embedding of link maps into multimedia presentations. Challenges in meeting the demands and requirements of the native features of each will be explored, as well as how they have been addressed. Implications for teaching and learning, in terms of the level of accommodation the environments provide are also discussed. In the process, our paper also provides an insight into the debate of the relative impact of teaching experience (or 'craft') compared to research findings on the design of successful teaching and learning tools, as well as the famous 'multimedia debate'.

## Background

The core subject matter of this paper, the integration of 'link maps' into multimedia, draws upon a range of educational research areas. Of particular significance, is the research and literature regarding 'concept maps', 'link maps' and educational multimedia. The research surrounding these areas is vital in informing, influencing and grounding our research.

## Concept Maps

Since Joseph Novak's conception of them in the 1970's, concept maps have made a significant impact on educational discourse, and today pervade most levels of education in various incarnations. Concept maps are essentially graphical tools that serve to organize and represent knowledge. They include concepts which are usually enclosed in some sort of frame (overall often called a 'node'), and relationships between various concepts are indicated by a connecting line linking two concepts (often called 'links'). Often, words on the line, called 'linking words' or 'linking phrases', specify the relationship between the two concepts (Novak & Cañas, 2006).

Concept maps have their foundation in David Ausubel's psychology and learning theory. Of central importance to Ausubel's learning theory is the influence students' prior knowledge has on subsequent meaningful learning. Much research has been undertaken regarding the efficacy of concept maps, and has demonstrated that they do indeed promote meaningful learning in a range of contexts (Horton, McConney, Gallo, Woods, Senn, & Hamelin, 1993). As the proliferation of computers into schools increased over the last two-decades, the research area of computer based concept mapping also emerged. Within this field, the benefits of computer based concept mapping have also been discussed (Anderson-Inman & Zeitz, 1993), and demonstrated (Chang, Sung, & Chen, 2001) - however the research base on computer based concept maps is far less extensive than that on 'traditional' concept maps. Of specific relevance to our purpose, the research concerning science education has also shown the benefits of concept maps as a learning and instructional tool (Roth & Roychoudhury, 1993).



## **Link Maps**

Recently, research undertaken within the School of Physics at the University of Sydney has yielded the incarnation of ‘link maps’, graphical representations similar to concept maps, but with specific consideration given to the physics education environment in which they are employed. Link maps are informed by cognitive load theory, a psychological framework which addresses memory and learning (for more information see: van Merriënboer & Sweller, 2005). Link maps are designed by using key physics ideas and selected relationships, that seek to gradually form the basis of some sort of schema within learners (Lindstrøm & Sharma, 2009). There are significant differences between link maps and concept maps, due to the unique features of physics as a subject and the related educational consequences. One such difference regards the nature of the composition of link maps. This arises due to the purpose of link maps to focus on trying to represent the natural structure of physics for learners, rather than being constrained by trying to fit into the standard concept map representation. Within concept maps, each node is often only representative of the text within it – the physics-based nodes of link maps however, are representative of much broader content, such as entire physical phenomena or laws. Additionally, links between nodes often do not have linking words or phrases, and information in the form of mathematical equations, an inherent part of physics, are also integral to the composition of link maps.

Implementation of link maps as a learning tool also differs from the wide array used for concept maps. Insofar, implementation has centred on first year physics university undergraduates in special enrichment tutorial sessions called ‘map meetings’. Within these sessions, students were guided through the progressive composition of the link map by an instructor in a stepwise fashion, with student interactivity and input utilised in the process. Students were then given problems designed to develop students’ problem solving skills and consolidate the link map, working through these in collaborative groups. To finish the session, the instructor would interactively explain problems identified by students as challenging. Recent findings on the effectiveness of link maps and map meetings on student achievement and self-efficacy have been positive (Lindstrøm and Sharma, 2009). Using measures of exam results and longitudinal surveys, results from this study suggest 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 using more traditional instruction methods.

## **Multimedia**

Multimedia is a force that cannot be ignored in the modern educational context. Much ink has been spilt in the literature concerning the effectiveness of multimedia and its differing incarnations. One of the fundamental debates in educational multimedia concerns the influence of the type of media to learning. 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 to others (Kozma, 1994) or that the ‘replaceability’ of media characteristics sees the particular form of media as irrelevant (Clark, 1994).

The current understanding of the importance of media is still very much debated. However work by Richard Mayer has seen the development of a methodology for effective multimedia practice, through a ‘cognitive theory of multimedia learning’, merging notions of educational psychology, cognitive load theory and multimedia learning (Mayer, 2005). This theory at its core provides a solid educational research basis for the development of multimedia resources and as such is gaining significant influence in the development of multimedia tools. Recent research projects by Physics Education Research efforts have utilised Mayer’s design principles and demonstrated the effectiveness of utilising multimedia such as videos or computer simulations in physics education at both high school and university level (Mayo, Sharma & Muller, 2008; Muller, Lee & Sharma, 2008).



## Research Aim

The educational benefits of the research areas discussed above are all based on a solid research basis. What our research aims to do is to successfully incorporate the principles of both concept and link maps into multimedia design of physics education tools. We will seek to implement the concept/link map research framework into both a video presentation and an interactive computer simulation for Year 12 HSC physics. Using these, we will investigate the effects that using such tools have on students' achievement and views towards physics. In doing so, we wish to propose a concrete, research-based methodology on the implementation of the concept/link map idea into multimedia-based physics instruction. Along the way we will also provide another viewpoint on the 'multimedia debate'.

## Rationale

Our integration of research on concept maps and link maps into multimedia representations is based on the reasonable attempt to consolidate the educational benefits of these various forms into one package. Physics represents a unique field of study, and as such link maps, rather than concept maps will be embedded in our physics education multimedia. Nonetheless the commonalities between the two fields as well as the significant relevant research on computer-based concept maps demands that the research on concept maps is also incorporated into our methodology. Much literature concerning concept maps is based on their use as an evaluation tool. Our multimedia tool is novel in that it seeks to implement the link maps as a primary or secondary teaching tool.

Both video and computer simulation multimedia representations are used to investigate how the different native features of each can be utilised in the presentation of link map content to students. Instead of seeking to examine how each multimedia fares on a 'replaceability' basis, the instructional effectiveness of each multimedia will be examined with its unique features emphasised. Computer programs possess the ability for allowing learners to significantly interact with the learning materials. The benefit of utilising computers in concept mapping has been established, and we seek to investigate the benefits of incorporating link maps into this environment. On the other hand, video multimedia allows for a much more guided learning structure allowing it to somewhat resemble map meetings more closely. Video multimedia also has a significant research foundation, and has added benefits such as portability and relative ease of creation.

One of the central tenets of the process of our research is to provide a research based methodology in the development of educational multimedia and technologies. Through testing of the efficacy of multimedia compositions, we emphasise a scientific approach to educational multimedia design. This is opposed to what is commonly known as a 'craft' design approach which gives less emphasis to results and evidence and more emphasis to the experience and skills of the designer. Though there is nothing inherently wrong with considering the experience of designers, the danger lies in if that is all that is considered. Such extreme craft approaches to development do not result in authentic educational tools (Clark & Estes, 1999). The provision of a process for embedding research methods into educational multimedia seeks to provide a research based methodology and move away from 'craft' approaches to multimedia design.

Year 12 physics was chosen as the focus of this study because it lends itself greatly to the use of link maps in its syllabus material. Students are required to learn about concepts such as 'the motor effect' and 'electromagnetic induction', both of which incorporate many complex and interconnected pieces of knowledge that students often find hard to link to one another. It is with this notion that we seek to examine the effects of our link map multimedia on students' views and conceptions of physics, whether students gain a more cohesive view of the nature of physics or consider it as being just a bunch of discontinuous equations and laws. Such views are important to science educators as



they can have a distinct impact on both student motivation, and possibly even future education and career choices.

## Design

Mayer's principles of multimedia learning (Mayer, 2005), informed by cognitive load theory, were used as the overarching framework in designing the link map multimedia. Principles such as the multimedia principle, modality principle, split attention principle and redundancy principle are all utilised in transferring link maps into both the video and computer environment. Mayer's 'multimedia principle' states that people learn better from words and pictures than words alone. Related to this, the 'modality principle' concerns the issue that it is more beneficial to have some information presented as audio and some as visual rather than all presented fully as audio or visual. The 'split-attention principle' states that when designing instruction, it is important to avoid formats that require learners to split their attention between, and mentally interrogate multiple sources of information. The 'redundancy principle' suggests that redundant material interferes with rather than facilitates learning with redundancy occurring when the same information is presented in multiple forms or is unnecessarily elaborated.

Both multimedia, as with the link maps embedded within them, are also informed by the framework of constructivism. In their implementation, students will be required to work in groups when interacting with the multimedia. Regarding Mayer's multimedia principles, both multimedia use the 'personalisation principle', which states that conversational voice styles are more beneficial to formal styles, in the narration within each context. Each of the multimedia during implementation will at some stage require students to engage in construction of their own link maps and as such, have embedded within the 'worked-out examples principle' – where the design ensures that the method used in students' construction of link maps is clearly guided by examples and instructions. This very much blends into the 'guided discovery principle', in which we ensure students are provided with integrated guidance within the multimedia design.

The design of the video multimedia very much draws from the instructional processes present in map meetings. Essentially, the video will take students through the 'building' of the link map from its foundational concept, for example electromagnetic induction. The screen essentially consists of a 'talking head' explaining the building of the map with digital graphics representing the components of the link maps shown on the screen concurrently. Mayer's 'image principle' states that people do not necessarily learn more deeply when the speaker's image is on screen – the choice has just been made as a means of emphasising standard conversational style in accordance with the 'personalisation principle' and the spirit of the original map meetings. Narration and graphics are used in accordance with the 'multimedia principle' and 'modality principle'. A screenshot of the video multimedia is provided in Figure 1.

Due to its ability for interactivity, the design for the computer program (written in *Flash* for ease of access through an internet browser) is significantly different to that of the video. Where in the video, students directly receive information of the composition of a link map without any input or feedback on their conceptions, the computer program provides a substantial scaffold for students to construct the own link map. Students have the ability to drag-and-drop elements onto a skeleton link map, with audio feedback given depending on their actions. This feature can be seen in Figure 2, as well as the scaffold of the skeleton link map. The computer-based multimedia is similarly stepwise in the instruction of student and all extraneous processing load is reduced as much as possible. The computer program also utilises narration in accordance with 'multimedia principle', 'modality principle' and 'personalisation principle'.

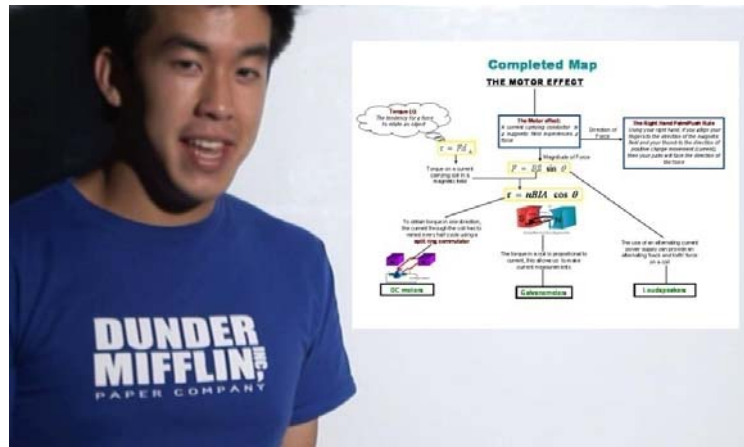


Figure 1: Screenshot of video

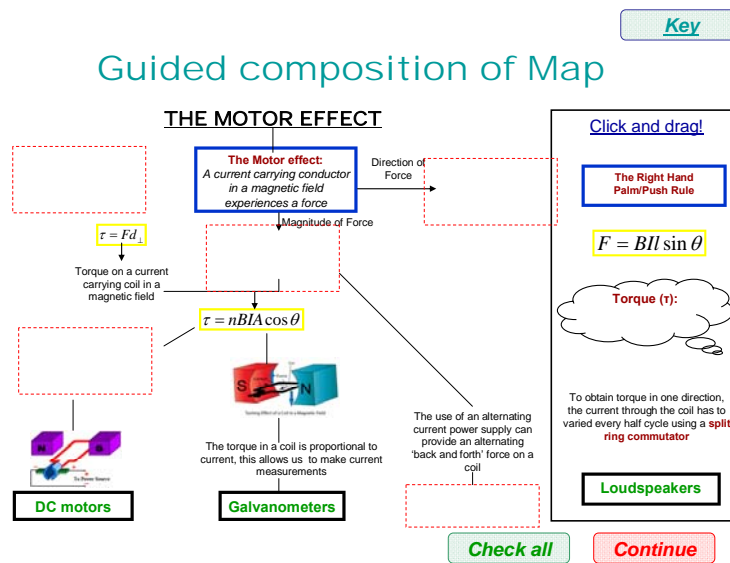


Figure 2: A screenshot of the computer program

In the overall design of our two multimedia tools, we have focussed on the utilisation of each multimedia’s native features. For example, in embedding link maps into a computer-based environment we have ensured that the interactive features of computer-based multimedia are used. In the same way, the video multimedia tool is created utilising video’s ability to present a flowing, personalised dialogue. The native features and opportunities of each multimedia need to be further considered when implementing the tools into the pedagogy of the teacher in an educational setting.

## Future directions

### Assessing student achievement and views towards physics

In addressing our aim in using a scientific approach in the design of multimedia we will need to measure the results of their implementation. This will be carried out in the future by creating ‘treatments’ around each computer-based or video multimedia and implementing them in various Year 12 physics classes around the greater Sydney area. To measure achievement gains, a pre/post test methodology will be used to assess the effectiveness of these treatments in terms of academic performance. Data on how our link map multimedia effect student conceptions of physics will also be measured by the administering of a survey before and after the treatments. The effects of the





treatments on student's feelings toward physics as a subject will be gauged using a variation of the Maryland Physics Expectations (MPEX) survey (Redish, Saul, and Steinberg, 1998).

### **Implications for wider science education**

Although the methods and research discussed here are focused around our research aims in physics education, the ideas presented in this paper have implications for other scientific disciplines. Indeed, the attempted reproduction of expert schemas in novices through the use of link maps, is perhaps a process that all scientific disciplines should use when attempting to use concept maps as a teaching tool.

### **Conclusion**

This paper has discussed the embedding of research principles surrounding concept maps, link maps and multimedia into the creation of link map multimedia. In doing so we provide a framework for a research based methodology approach to the design of educational multimedia. The next step in the process is to gather research data on the effects of the multimedia on physics education and further investigate their implications for science education.

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