DIGITAL LEARNING OBJECTS: DESIGN FOR LEARNING

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Abstract

This research investigated relationships between the information presentation modality of a digital learning object (DLO) and learning. It also investigated relationships between DLO design features and participants perceptions of learning. DLOs are a type of learning material defined for the purposes of this research as ‘digital, multimedia learning materials that support the learning of specific concepts by enhancing, amplifying, and guiding the cognitive processes of learners’. In this research participants used one of three DLO variants that presented information about the forces affecting an airplane in flight. Each variant presented identical information but used a different modality. The information presentation modalities were, on screen text and an illustration, narrated text and an illustration, and on screen text and narrated text and an illustration. Using a mixed method case study methodology, data was gathered using pre and post assessments, an online user perception survey (UPS), and one to one interviews. Within the limitations of this research, the results suggest that use of any variant of the forces of flight DLO influenced participants learning. The modality and other DLO design features, such as interactivity, also influenced learning and participants’ perceptions of learning. The researcher argues for the need to consider the cognitive and affective processes of learners when creating DLOs. A need for further research that explores the effects of different DLO designs upon learning is identified.

Glossary

This section provides clarification of some of the key terms used in this research.

Cognitive affective theory of learning from media (CATLM) Moreno (2006)	A theory that proposes that people learn from pictures and words. This theory is based upon the assumptions; people have separate channels for processing visual and verbal information, each channel is limited in capacity, learning involves active cognitive processing and learning from words and pictures is influenced by the beliefs and emotions of learners
Cognitive theory of multimedia learning (CTML) Mayer (2005, 2014)	A theory that posits that people learn from pictures and words. This theory is based upon the assumptions; people have separate channels for processing visual and verbal information, each channel is limited in capacity, and that learning involves active cognitive processing.
Cognitive load theory (CLT) Sweller (1998, 2005) Sweller, J., Ayres, P., & Kalyuga, S. (2011)	An instructional theory that considers the limitations of working (short-term) memory.
Cognitive capacity Mayer (2005, 2014)	The total amount of work that can be supported by a learner's working (short-term) memory.
Coherence principle Mayer (2005, 2009, 2014)	States that people learn better when non-essential material is excluded.

Digital Learning Object (DLO) Kay & Knaach (2007, 2012) Kay (2012)	Digital, multimedia learning materials that support the learning of specific concepts by enhancing, amplifying, and guiding the cognitive processes of learners.
Dual-coding theory (DCT) Paivio (1986, 2007) Clark & Paivio (1991)	Refers to dual channels used in the sensing, mental processing and storing of visual and verbal information.
Long term memory Sweller (1998, 2005) Sweller, J., Ayres, P., & Kalyuga, S. (2011)	A memory store that holds large amounts of information. In contrast to working (short-term) memory the long term memory can store information indefinitely and is unlimited in its capacity.
Mental model Sweller (1998, 2005) Sweller, J., Ayres, P., & Kalyuga, S. (2011)	A mental representation of some concept that is stored in the long-term memory.
Modality principle Mayer (2005, 2014) Sweller (2005)	Proposes that people learn better from text and pictures if the text is presented as spoken rather than written text.
Multimedia instruction Mayer (2001, 2009)	The presentation of information as pictures and words intended to promote learning.
Multimedia principle Mayer (2001, 2009)	Describes how people learn from words and pictures. The principle states that people learn better from pictures and words than from words alone.
Presentation design Churchill (2007, 2013, 2014)	The arrangement of content and screen design features of digital learning objects.

Prior knowledge principle Mayer (2005, 2009, 2014)	States that most principles of the Cognitive Theory of Multimedia Learning are dependent upon the extent of the learner's prior knowledge.
Redundancy principle Mayer (2005, 2009, 2014)	A principle that proposes that people learn better when duplicate information is not presented at the same time.
Segmenting principle Mayer (2005, 2009, 2014)	This principle proposes that people learn better from multimedia instruction when they have control over the pace of instruction.
Spatial Contiguity principle Mayer (2005, 2009, 2014)	A principle that identifies that people learn better when related words and pictures are spatially positioned close together.
Split-attention effect Mayer (2005, 2009, 2014)	The presentation of multiple sources of information required for understanding in the same or different media modalities that are not physically integrated is detrimental to learning.
Temporal contiguity principle Mayer (2005, 2009, 2014)	People learn better when related animations and narrations are presented at the same time.
Working (short-term) memory Sweller (1998, 2005) Sweller, J., Ayres, P., & Kalyuga, S. (2011)	A limited capacity store for holding and manipulating sounds and images.

Table 1. Clarification of key terms

Chapter 1 Introduction

This chapter begins by providing an overview of the context and rationale of this study and then introduces key concepts underpinning this research. The chapter concludes with the identification of the relevance of this study to learning and teaching.

Learning and teaching in the 21st Century

Prior to the 21st century, education was typically teacher centric with content transmitted from the teacher to the learner (Wan and Gut, 2011; OECD, 2009). The advent of powerful and accessible information and communication technologies (ICTs) e.g. computers and the internet in the late 20th Century, the accompanying technology driven rise of globalism and advances in psychology and the neurosciences have contributed to the emergence of a new view of learning as learner centric, active, and collaborative (OECD, 2013; Orlando, 2012; Wan and Gut, 2011; Mayer, 2001, 2005, 2009). The evolution of education from a traditional lecture-by-expert model of instruction to learner centric pedagogies requires a shift in the roles and attitudes of teachers (Wismath, 2013). Although there is contention as to the degree to which teachers are engaging in a process of evolving their teaching practice (Orlando, 2012), the impact of digital technologies upon teaching and learning is evidenced by the proliferation in the use of educational digital resources made available via the Internet. (OECD, 2013; Orlando, 2012; Wan & Gut, 2011).

Educational digital resources

Educational digital resources are digital artefacts of cultural, historical and/or scientific interest. They exist in a wide range of media formats and include artefacts such as digitalized photographs, art works, video clips, speeches, songs and digital models. In New Zealand the popularity of educational digital resources amongst educators is attested to by the existence of the New Zealand Ministry of Education's Digistore (http://Digistore.tki.org.nz/ec/p/home), an online repository of educational digital resources designed specifically for use across the New Zealand curriculum, from early childhood to senior secondary. As of April 2014, Digistore contained 3407 individual digital learning resources of which 2327 are interactive resources and the balance are film clips, videos, animations, images, sound files and historical documents. Digistore has approximately 100 unique visitors per day (T. Dobie, personal communication, March 31, 2014)). Internationally, educational digital resource repositories include MERLOT and the Commonwealth of Learning 'Learning Object Repository'. MERLOT is managed and hosted by California State University Center for Distributed Learning (CSU-CDL at www.cdl.edu) while the Commonwealth of Learning 'Learning Object Repository' is headquartered in British Columbia, Canada. Collectively, such repositories' provides teachers with free access to potentially tens of thousands of educational digital resources.

Digital Learning Objects

Digital Learning Objects (DLOs) are a type of educational resource defined for the purposes of this research as 'digital multimedia learning materials that support the learning of specific concepts by enhancing, amplifying, and guiding the cognitive processes of learners'. DLOs exist in a myriad of forms and may function as presentation objects, practice objects, simulation objects, information objects, contextual representation objects and conceptual models (Churchill, 2014). As such, DLOs range in complexity from Microsoft PowerPoint slides created by a teacher to accompany face-to-face instruction through to interactive simulations and fully immersive virtual reality environments created by specialist computer programmers.

The affordances of contemporary computing technologies enable the creation of DLOs that utilize a wide range of multimedia e.g. animation, video, text, and illustrations, and provide for a diversity of interactive user experiences in a myriad of different combinations (Churchill 2007, 2013, 2014). Computer applications such as Microsoft PowerPoint and Microsoft Movie Maker (amongst many others) make available to educators and instructional designers the tools with which to create DLOs. Furthermore, DLO repositories' such as Digistore and Merlot provide access to DLOs to educators worldwide. While the literature identifies that positive learning benefits can arise from the use of DLOs, the literature also identifies that poorly designed DLOs can be detrimental to learning (Mayer, 2001, 2005, 2009, 2014; Issa, Schuller, Santacaterina, Shapiro, Wang, Mayer & DaRosa, 2011; Crooks, Cheon, Inan, Ari and Flores, 2012; Issa, Mayer, Schuller, Wang, Shapiro & DaRosa, 2013; Churchill, 2014).

Media, multimedia, multimedia learning and modality

For DLOs to have positive educational outcomes, DLO designs need to be aligned with how people sense and process multimedia learning materials and how people feel about engaging with multimedia instruction (Churchill, 2014; Kim, Kim and Whang, 2013; Mayer, 2001 2005, 2009; Moreno, 2006; Issa, Schuller, Santacaterina, Shapiro, Wang, Mayer & DaRosa, 2011; Issa, Mayer, Schuller, Wang, Shapiro & DaRosa, 2013). But what are media, multimedia, multimedia learning and modality?

Moreno (2006) and Mayer (2001, 2005, 2009, 2014) use the word media to refer to the vehicle of instruction; for example, a lecture presentation, a textbook, a computer or a DLO. As such, in the context of this research the 'forces of flight DLO' is the media.

According to Mayer (2001, 2005, 2009, 2014) and Moreno (2006), the term multimedia has two meanings. One meaning is the form in which information is represented. For example, the representation of information as pictures or as words. The second definition of multimedia refers to the sensory mode(s) used to sense information, for example auditory, visual, tactile, olfactory and gustatory sensing.

Mayer (1997, 2001, 2005, 2009, 2014) defines multimedia learning as learning from pictures and words. This includes learning from textbooks that contain words and pictures, DLOs that contain animations and narrations and face-to-face presentations that contain spoken words and illustrations presented on slides. As such, multimedia learning does not necessarily involve DLOs or any other type of ICT (Mayer, 1997, 2001, 2005, 2009, 2014; Moreno, 2006).

Modality is the sensory channel that is used by learners when they initially process an instructional message (Moreno, 2006). Human modalities include: auditory, visual, tactile, olfactory and gustatory. Verbal information (words) may be presented in both visual and auditory modalities. For example, on-screen text (words) is verbal information presented in a visual modality, while a spoken word is verbal information presented in an auditory modality.

DLO Design and the Cognitive Theory of Multimedia Learning

DLO presentation design concerns the media modality of DLO content and other DLO design features. For DLOs to have positive educational outcomes DLO presentation design needs to be aligned with how people sense and learn from multimedia materials (Churchill, 2014). Two contemporary and relevant psychological theories pertaining to how people learn with multimedia materials are the Cognitive Theory of Multimedia Learning (CTML) (Mayer, 2005, 2014; Sweller, 2005) and Dual Coding Theory (DCT) (Paivio, 1986, 2007). Both CTML and DCT describe innate human cognitive architecture and associated processes and explain how people process different types of information and how people learn with their visual and auditory senses (Sweller, 2005; van Merriënboer & Kester 2005). These theories are of relevance to DLO presentation design as they provide a mechanism for explaining why and how presentation design can impact upon the learning efficacy of a DLO (Churchill, 2014). The Cognitive Theory of Multimedia Learning (CTML) provides empirically tested guiding principles concerning the presentation of multimedia content delivered via computer screens and the influence of multimedia materials on learning (Mayer, 2005, 2014). The CTML identifies relationships between instructional message media modality and learning, asserting that working memory can effectively be expanded if a mix of sensory modes (auditory and visual) is used rather than a single sensory modality (visual or auditory) when presenting information using computer screens. A theoretical foundation of the CTML is DCT, which posits the existence of two independent, but complementary, cognitive systems. These systems operate in an additive manner to effectively increase the processing capacity of the working memory, increasing the likelihood of learning by the reduction of cognitive load. One sensory subsystem is used for the processing of verbal (descriptive) information. The second subsystem is used for the processing of pictorial (depictive) information (Paivio, 1986, 2007). DCT also proposes that the processing capacity of each of these subsystems is limited and that any subsystem overload can result in cognitive over-load which is detrimental to learning. The second theoretical foundation of the CTML is that learning is active and constructed rather than passive and transmitted (Mayer, 2005, 2014). Constructivism is a pedagogy that identifies learning as an active and dynamic process by which learners construct new ideas or concepts based on their current and past knowledge (Fletcher and Tobias, 2005).

Relevance of this thesis

This research investigates the proposition that DLO modality affects learning and that modality and other DLO design features, such as interactivity and usability, affect learners' perceptions of learning. Despite extensive historical empirical evidence supporting the modality effect (Mayer, 2001, 2005, 2009, 2014; Mayer and Moreno, 2003, Ginns, 2005, Moreno, 2006), Inan, Crooks, Cheon, Ari, Flores, Kurucay and Paniukov (2015) argue that there is a lack of clear guidelines for people creating DLOs regarding modality effects. They call for further research to investigate the factors that influence the modality effect. As such, this thesis contributes to an emerging body of contemporary research investigating modality effects and the factors that influence modality effects in the context of DLO design. In this study participants used one of three variants of a digital learning object created by the researcher that provided information about the forces affecting an aircraft in flight. Each DLO variant presented learners identical information in different modalities (written text, spoken text and combined written and spoken text). Data was collected from participants before and after using a DLO variant via an online pre and post assessment intended to measure changes in learning performance as a consequence of engaging with the DLO. Further data was gathered via an online survey to gauge participants' perceptions of learning arising from their use of the DLO variants. One to one interviews were also conducted with six participants in order to delve deeper into perceptions of learning identified in the survey. Pre-post assessment, survey and interview data was analysed and used to answer the research questions:

1. How did the modality of instructional messages presented by the forces of flight digital learning object affect learning and perceptions of learning?
2. What properties of the forces of flight digital learning object did users perceive as supporting learning?

In this chapter, a brief overview of the research rationale and the context of this study have been provided. Chapter 2 reviews literature concerning the affects of multimedia instruction upon learning. Chapter 3 describes the research methodology, the research participants and discusses the validity and reliability of the data and ethical considerations. In Chapter 4 the findings from the pre-post assessment, user perception survey (UPS) and one to one interviews are presented. Finally, Chapter 5 concludes this thesis, by discussing the findings of the study, providing recommendations for practice and identifying areas for future research.

Chapter 2 Literature review

2.1 Introduction

DLOs present information to learners in different media modalities. For example, information may be presented as illustrations, spoken words, written words, video and/or animations. This diversity of media is commonly called multimedia (Churchill, 2014). The presentation of multimedia information to learners has been demonstrated to influence learning performance. Richard Mayer's Multimedia Principle empirically demonstrated that people learn better from words and pictures presented together than from words alone (Mayer, 2001, 2009). Literature about learning with multimedia is situated in four separate but related domains, the cognitive, the multimedia, the curricula and the affective (Sweller 2005; Sweller, Ayres & Kalyuga, 2011; van Merrienboer & Kester, 2005; Mayer, 2001, 2005, 2009, 2014; Kim, Kim and Whang, 2013). The cognitive domain describes mechanisms of how the presentation of multimedia learning materials influences learning. The multimedia domain describes the influence of multimedia materials on learning. The curricular domain describes how DLOs are used in teaching while the affective domain considers the relationships between learner characteristics such as the extent of existing knowledge, emotions and beliefs and DLO design features. This chapter reviews literature from each of these domains. The chapter begins with a review of literature concerning cognitive theories of multimedia learning, followed by a review of the literature concerning the modality principle and other multimedia design principles arising from the cognitive theories of multimedia learning. The application of multimedia design principles to DLOs in medical education is then considered before concluding with a review of literature concerning the influence of learners' emotions while learning from multimedia DLOs.

2.2 Cognitive theories of multimedia learning and DLO design

Cognitive theories about learning from DLOs describe the sensory and mental systems and processes that explain how people learn using their senses and how people process information. These theories are of relevance as they provide DLO designers with information about how people sense and process information. Paivio's (1986) Dual Coding Theory (DCT) is one theory that describes how people sense and process information. Other relevant theories are; the Cognitive Load Theory (Sweller, Ayres & Kalyuga, 2011); the Cognitive Theory of Multimedia Learning (Mayer, 2005, 2014) and the Cognitive-Affective Theory of Learning from Media (Moreno, 2006).

2.2.1 Dual coding theory

Dual Coding Theory (DCT) describes how people make meaning from information presented in verbal (words) and non-verbal (pictures) modalities (Paivio, 1986). DCT proposes that people possess two sensory-cognitive systems which are independent yet complementary. One sensory-cognitive system is responsible for the sensing and cognitive processing of non-verbal (pictures) information. The other system is responsible for the sensing and cognitive processing of verbal (words) information. Information represented by words may be presented visually as written words or as spoken words. Eyes sense visual stimuli such as pictures and written words while ears sense auditory stimuli such as spoken words. . Cognitive processing of sensed information occurs in the brain, initially in the working memory and ultimately in the long-term memory. According to DCT, verbal and non-verbal information is represented and processed in the short and long term memory as two distinct codes; symbolic codes and analogue codes. Symbolic codes are verbal mental representations (spoken or written words) while analogue codes are non-verbal mental representations (pictures). Information recalled from the long-term memory may be as non-verbal (pictures) and/or verbal (words). For example, if the word "boat" and a photograph of a boat are presented this information is stored in the long-term memory as both the word "boat" and a mental image of the photograph of the boat. When this information is recalled it may be remembered as the word "boat" and/or as a visual image of a boat.

DCT proposes that learning occurs as a consequence of the cognitive processing of sensed verbal and non-verbal information. DCT describes three types of cognitive processing. These are representational, associative and referential processing. According to Clark and Paivio (1991), representational processing concerns the formation of mental representations as words (logogens) and/or pictures (imagens) that are analogous to the presented information. Associative processing concerns the creation of connections between different pieces of information made within either the verbal or non-verbal sub-system. Referential processing concerns the creation of connections between mental representations that exist in the non-verbal and verbal sub-system. Sweller (1988, 2005) and Mayer (2001, 2009) propose that as a consequence of media modality effects on representational, associative and referential cognitive processes, the presentation of information in different modalities may act to either facilitate or impede learning. Cognitive load theory (Sweller, 2005; Sweller, Ayres & Kalyuga, 2011) proposes that ineffective referential and associative processing places an extraneous cognitive load on the learner that is detrimental to learning. For example, the presentation of an illustration about a concept of which the learner has no prior knowledge and which makes no sense if not accompanied by a verbal description (for example, visual text labels) requires the learner to invest cognitive effort (referential and associative processing) attempting to understand the illustration. Without the required prior knowledge and the presentation of all of the information required for understanding an extraneous cognitive load is experienced by the learner, to the detriment of their learning. Conversely, the presentation of relevant words (verbal) and pictures (non-verbal) allows the learner to effectively engage in referential and associative (cognitive) processing, thus facilitating learning. As such, DLO designers need to make media modality decisions that are aligned with innate human cognitive architecture and processes as identified by DCT. Furthermore, understanding of cognitive processes enables DLO designers to create DLOs that employ novel and effective instructional design approaches. For example, the presentation to learners of pictures (non-verbal) as prompts for learners to generate verbal (words) responses. This is an example of the use of referential processing as an instructional design approach.

2.2.2 Cognitive load theory

Cognitive Load Theory (CLT) proposes that representational, associative and referential processing as described by DCT imposes a cognitive load upon the learners (Sweller, 2005; Sweller, Ayres & Kalyuga, 2011). Cognitive load is the mental effort a learner has to invest in order to make sense of presented information and representational, associative and referential cognitive processing happens in the short and long-term memory. According to CLT, the short-term memory is limited in its processing capacity and surpassing this capacity imposes a high cognitive load on learners that is detrimental to learning. Conversely, spreading the cognitive load across the verbal and non-verbal channels may facilitate learning. CLT identifies that although they are independent, the verbal and non-verbal sensory cognitive systems can act in an additive manner to reduce cognitive load, increasing the capacity of the short-term memory by spreading the cognitive load across both sub-systems (Sweller, 2005; Sweller, van Merriënboer & Paas, 1998). According to Sweller, Ayres & Kalyuga (2011), three types of cognitive load exist. These are intrinsic, extraneous and germane cognitive load. Intrinsic cognitive load is the cognitive load imposed upon learners as a result of the complexity of the topic of instruction. Extraneous cognitive load is the load imposed upon learners as a consequence of the use of inappropriate instructional designs such as the presentation of redundant or irrelevant information and/or activities that require learners to invest cognitive energy in work not essential for learning. Germane cognitive load is the cognitive load imposed upon learners engaged in meaningful learning activities. For example, providing learners with formative assessments requires learners to invest cognitive resources in engaging with this learning activity. Intrinsic, extraneous and germane, cognitive load are additive and an aim of DLO designers is to minimize extraneous cognitive load in order to free working memory capacity to deal with intrinsic and germane cognitive loads. The media modality of information presented by a DLO could impose an extraneous cognitive load upon learners that is detrimental to learning (Mayer, 2005, 2009; Moreno, 2006; Sweller, Ayres & Kalyuga, 2011). This is a consequence of the presentation of too much information in a single mode, the limited sensing capacity of the eyes and ears and the limited processing capacity of the short-term memory. Sweller (1998, 2005) and Sweller, Ayres & Kalyuga, (2011) propose that sound instructional design requires knowledge of innate human cognitive architecture and that a lack of knowledge of human cognitive processes, such as the characteristics of short and long term memory and cognitive load, may result in designs which are detrimental to learning. As such, an understanding of CLT is essential to DLO designers in order to create DLO's that support rather than detract from learning.

2.2.3 Cognitive theories of multimedia learning

Cognitive Theory of Multimedia Learning

The Cognitive Theory of Multimedia Learning (CTML) (Mayer, 2005, 2014), and Cognitive-Affective Theory of Learning with Media (CATLM) (Moreno, 2006) are cognitive instructional design theories from which a number of evidence based multimedia design principles' relevant to the creation of DLOs have been derived (Issa, Schuller, Santacaterina, Shapiro, Wang, Mayer & DaRosa, 2011; Issa, Mayer, Schuller, Wang, Shapiro & DaRosa, 2013).

Mayer (2001, 2005, 2009, 2014), Moreno (2006) and Fletcher & Tobias (2005) conceptualize the theoretical foundations of CTML in Baddeley's (1986) model of working memory, Paivio's (1986, & 2007) Dual-coding Theory (DCT) and Sweller's (1998, 2005) Cognitive Load Theory (CLT).

CTML is based upon three assumptions:

1. The dual channel assumption that proposes that humans have separate sensory and cognitive channels for sensing and processing auditory and visual information (as per Paivio's Dual Coding Theory)
2. The limited capacity assumption which posits that both the auditory and visual sensing and processing channels and the working memory are limited in capacity (as per Sweller's Cognitive Load Theory)
3. The active processing assumption that states learners must actively process sensed

information by selecting, and organizing information within and between the two processing channels present in the working (short-term) memory and integrating this with information retrieved from the long-term memory (Clark & Paivio, 1991; Sweller, 2005; Mayer, 2009, 2014).

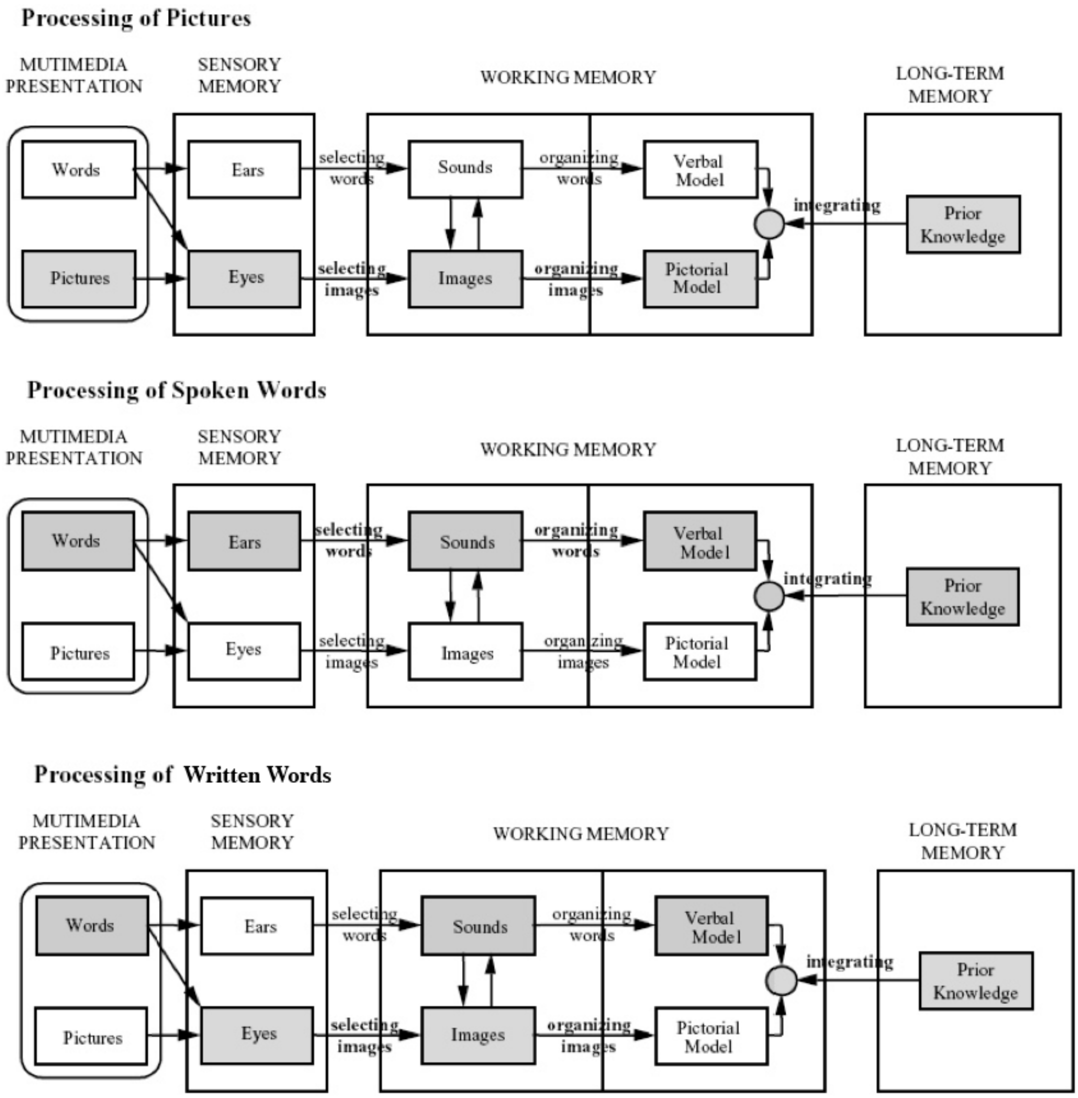

Figure 1. Cognitive processing of words and pictures (Mayer, 2005, p.43)

Cognitive-affective theory of learning from media

Cognitive-affective theory of learning from media (CATLM) (Moreno, 2006) is an extension of CTML that includes affective and metacognitive attributes of learners as part of its framework. According to Mayer (2009, 2014), theories on multimedia learning have traditionally focused on cognitive processes associated with learning such as selecting relevant information, organising selected information and integrating this with existing knowledge, while the influence of the affective characteristics of learners such as motivation and emotion have not been explored to any great extent. Moreno's (2006) CATLM includes these elements. A review of the literature concerning the influence of learner affective characteristics (emotions, beliefs, expectations) and learning from multimedia instructional messages presented by DLOs is presented later in this chapter.

As with CTML, CATLM is based upon a number of specific assumptions, some of which are common to both frameworks. The assumptions that underpin CATLM are:

1. The presence of independent yet complementary verbal and non-verbal information processing channels (Baddeley, 1986).
2. The dual channel assumption that humans have separate sensory and cognitive channels for sensing and processing auditory and visual information (Paivio's Dual Coding Theory, 1986, 2007).
3. The limited capacity assumption which is that both the auditory and visual sensing and processing channels and the working memory are limited in capacity (Sweller's Cognitive Load Theory, 1988, 2005).
4. The active processing assumption that learners must actively process sensed information by selecting, organizing and integrating information within and between the two processing channels (Clark & Paivio, 1991; Sweller, 2005, Mayer, 2009, 2014).
5. Affective mediation assumes that learner motivational factors influence learning

by increasing or decreasing cognitive engagement (Mayer, 2009, 2014; Moreno, 2006)

6. The metacognitive assumption proposes that learner metacognition affects learning by influencing cognitive processing (Mayer, 2009, 2014; Moreno, 2006).
7. The individual differences assumption proposes that the traits of individual learners such as preferred learning styles and the extent of existing knowledge influences learning and learning from multimedia (Mayer, 2009, 2014; Moreno, 2006).

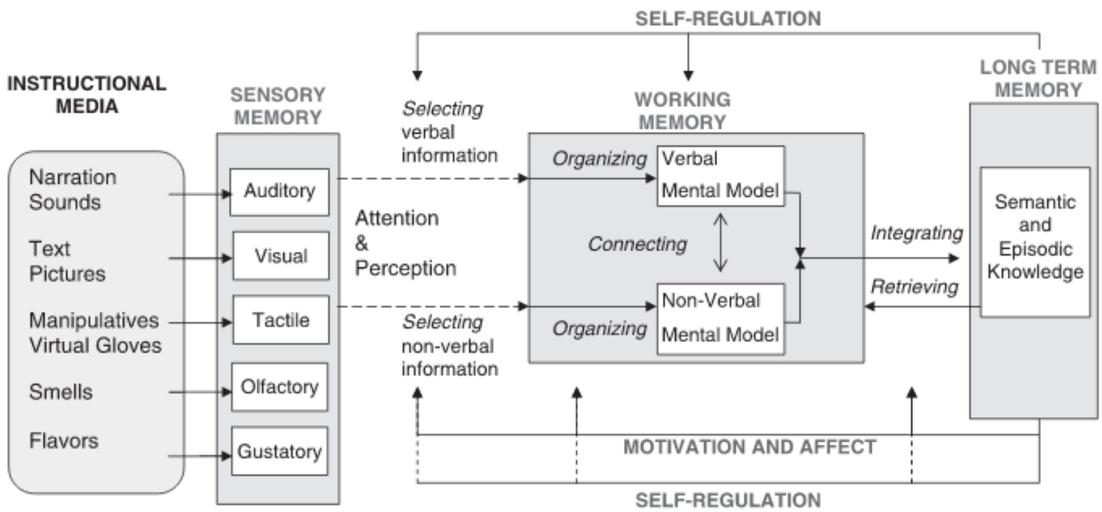

Figure 2. Cognitive-affective theory of learning with media (Moreno, 2006, p. 151)

Moreno (2006) and Mayer (2001, 2009) propose that the benefits of multimedia learning are a consequence of the instructional techniques embedded within the media (DLO) that promote learner understanding rather than arising from the media itself. Moreno's (2006) calls this 'method' or 'instructional design'. As such, Moreno (2006) argues for a method-affects-learning over a media-affects-learning hypothesis with regards to multimedia learning. The method-affects-learning hypothesis proposes that instructional designs embedded in media influence learning by promoting cognitive processing while the media used to deliver instruction does not (Moreno, 2006; Mayer, 2005, Clark, 1994). However, Moreno (2006) proposes that the method affects learning and the media affects learning hypotheses are not necessarily mutually exclusive. He forwards a 'media enables method hypothesis' that describes how the functional capabilities of different media, for example, a DLO, can enable effective instructional designs based on learning theories. This approach first requires the identification of the functional characteristics of the media, that is, what can it do, and then a description of how the identified functionality may support learning processes. The media enable method hypothesis is very relevant to DLOs as the sophistication of technologies available to educators allows for the creation of DLOs in a myriad of different forms and combinations of forms. For example, the forces of flight DLO used in this research functions simultaneously as both a practice object and as an information presentation object.

2.3 Split- attention principle

Presenting learners multiple sources of information, all of which are required for understanding, in the same or different modalities (verbal – written text, spoken text), non-verbal) is detrimental to learning when the sources of information are not physically integrated. For example, the following illustration (Figure 3) displays a version of the forces in flight illustration that could result in split attention and is an example of a non-integrated design. In this example the learners' eye has to move between the label associated with each force direction arrow and the key that associates label identifiers with the actual force names. The extraneous cognitive load placed on the user arises from having to sense the visually presented information that is not spatially co-located and with having to cognitively associate, for example, the upward indicating direction arrow with the letter "B" and the word "lift". This extraneous load is reduced when the force name is spatially located beside the force direction arrow. The principles of spatial and temporal contiguity are relevant to the split-attention effect. These are discussed later in this chapter.

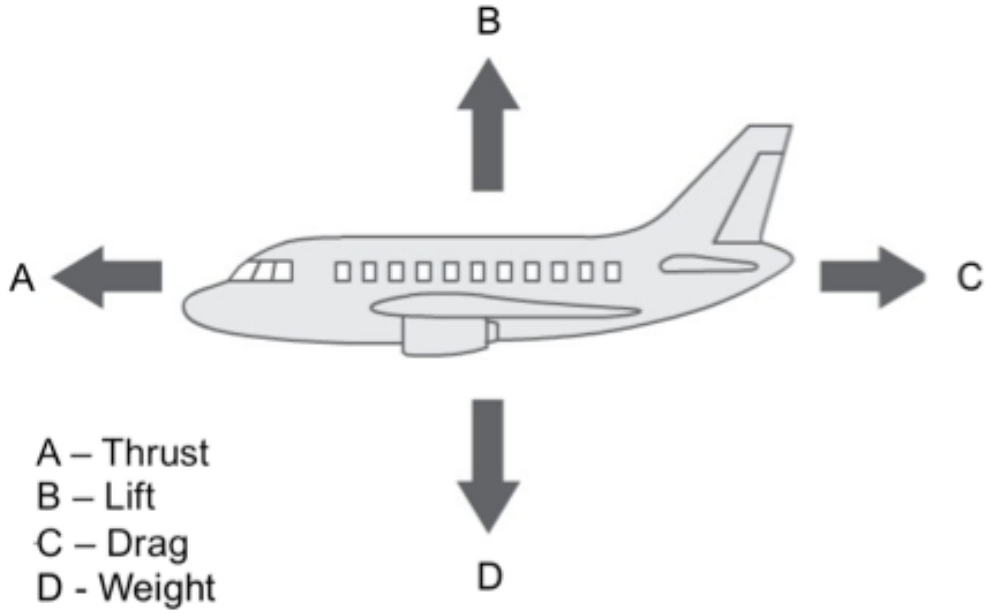

Figure 3. Example of the split attention effect (Science Learning Hub, The University of Waikato, www.sciencelearn.org.nz, 2011)

Tarmizi and Sweller (1988) were the first researchers to identify the existence of split-attention effects arising from the use of a learning object. Tarmizi and Sweller (1988) were investigating the effectiveness of worked examples on learning in geometry. The researchers did not obtain the results they were expecting and attributed this to the media format of the instructional materials that were presented to learners. In the initial experiment learners were presented with instructional material in the form of an illustration and separate but related written text. Tarmizi and Sweller (1988) proposed that the presentation of information as written text and an illustration imposed a large cognitive load on learners as it required the learners to split their attention between two different sources of visually presented information, both of which were required for understanding. To test their hypothesis a second experiment was conducted in which learners were presented with either integrated instructional material (written text was spatially located beside corresponding pictorial elements) and non-integrated (written text was not integrated with the illustration). They found that learners who used the integrated multimedia learning objects outperformed learners who used the non-integrated learning objects. Subsequent researchers have tested the split-attention effect in a range of subject areas (mathematics, physics, biology) using a range of media (paper based and computer delivered). For example, research conducted by Mayer, Steinhoff, Bower and Mars (1995) conducted a series of experiments in which undergraduate students were provided instruction about how lightening forms. Participants, who had varying levels of knowledge about this topic, were randomly assigned to a group that received integrated instruction or non-integrated instruction. Integrated instruction consisted of written text on a page and five related illustrations presented on the facing page. The illustrations contained labels and captions. The non-integrated instruction consisted of the text and images being presented in different booklets. The illustrations contained no labels or captions. After receiving instruction participants had to complete a problem solving test The results of this experiment showed that students with low prior knowledge of the topic who used the integrated materials performed better on problem solving tasks than low prior knowledge students who used the non-integrated multimedia resources.

With the advent of computers and digital learning objects some researchers proposed that split-attention effects might arise as a consequence of the media used to present instruction. That is, the presentation of information on paper and the presentation of information via a DLO. Cerpa, Chandler, and Sweller (1996) conducted a study investigating this. Participants received instruction in how to use a spreadsheet. One group of participants received integrated instruction delivered by a DLO. A second group received traditional non-integrated instruction delivered by a combination of paper and computer. The results showed that students who received integrated instruction presented by the DLO outperformed those who received non-integrated paper and computer instruction in text questions but only with test questions that tested knowledge on information of high element interactivity. Element interactivity refers to the number and complexity of related chunks of information that learners must comprehend in order to understand (Sweller, 2010). As such, Cerpa et al. (1996) identified that the split-attention effect is media agnostic and as such has relevance to DLOs as the presentation of information via a DLO may manifest or negate split-attention effects (Ayres & Sweller, 2005). This is dependent upon a DLOs design. Furthermore, results from Cerpa et al. (1996) identified a second factor that influences split-attention effects. This was element interactivity. Element interactivity is described later in this chapter.

Mayer (2005, 2014) describes a cognitive mechanism for the split-attention effect and argues that presenting learners with instructional information in formats and modalities that requires them to split their attention is detrimental to learning. Consequently the split-attention effect has important implications for the design of DLOs and other instructional materials. Despite the pervasiveness of the split-attention effect and the cognitive implications Ayres & Sweller (2005) observe that DLO designers seldom considered these. The split-attention effect has implications for the use of other types of ICTs in learning and teaching. An example of this is the web conferencing tool Adobe Connect Pro ©. The default GUI configuration allows for the simultaneous audio-visual presentation of information combining an auditory narration from a presenter speaking to visually presented information, for example, PowerPoint slides. The default GUI configuration also provides a synchronous online chat window that presents participants with chat messages simultaneously with the audio-visual presentation. As a consequence, participants have to split their attention between attending to the audio-visual presentation and the online chat. A possible consequence of this is that some information may not be sensed as learners' focus on one element to the detriment of the other. In the case of Adobe Connect it is easy to reconfigure the GUI to suit the activity and as such the chat window could be hidden until an appropriate time.

2.3 The modality principle

The modality effect is an evidence-based principle arising from CTML and CATLM (Mayer, 2005, 2014; Moreno, 2006). The modality principle proposes that spoken text is more effective than written text when presented with animations or pictures (Moreno, 2006). There is much empirical evidence for the modality principle. In an experiment conducted by Moreno (2006), seventy-eight university students viewed a multimedia presentation depicting the process of lightening formation. Forty participants' were presented with written explanations and illustrations explaining the process and thirty-eight participants viewed the illustrations while listening to narrated explanations. After viewing the presentation participants undertook recall and transfer tests. Moreno's results showed that learners exposed to the narration (auditory verbal information) plus illustrations presentation outperformed those who experienced the illustrations plus written text (visual verbal information) presentation in recall and transfer tests. Further research supporting the modality principle comes from an investigation conducted by Yaghoub Mousavi, Low, and Sweller (1995). Yaghoub Mousavi et al. (1995) presented learners geometry-related instructional materials consisting of a diagram and associated statements (words). A geometry diagram was presented in visual form while the associated textual information was presented in either a visual (written) or auditory (spoken) form. The researchers found that learners who were presented information in a dual mode as spoken words and illustration consistently outperformed learners who were presented the same information in a single visual mode (written words and illustration) in recall and transfer tests. A series of experiments reported by Tindal-Ford, Chandler and Sweller (1997) also supports the modality principle. These researchers hypothesised that instructional messages that presented information using dual auditory and visual modes would result in better learning outcomes than if the identical information was presented in a single mode (e.g. as visual text and illustrations). Tindal-Ford et al. (1997) conducted a series of experiments using a variety of instructional materials. The results of these experiments showed that learning performance in recall and retention was improved when learners were presented with instructional messages that consisted of a simultaneously presented visual illustration and auditory narration (dual mode). In contrast, learners presented with identical instructional messages in the form of visual illustrations and visual text (single mode) did not perform as well on the recall and retention tests. In these experiments Tindal-Ford et al. (1997) also identified a condition that influences the modality effect. This was element interactivity. Element interactivity is the number and complexity of related chunks of information that learners must simultaneously process in the working memory in order to understand the presented information (Sweller, 2010). Instructional materials with low element interactivity consist of chunks of information (elements) that can be processed individually and as such impose less of a cognitive load upon learners. High element interactivity instructional materials impose a high cognitive load upon learners that may exceed the capacity of working memory (Sweller, 2010). Tindal-Ford et al. (1997) predicted that low element interactivity instructional materials would not display modality effects, as the low intrinsic cognitive load did not approach the limits of the working (short-term) memory while high element interactivity instructional materials would display modality effects as the capacity of the working (short-term) memory is exceeded. In their experiments these researchers used a range of learning materials that were either high or low in element interactivity. The results supported the researchers predictions, identifying element interactivity as a condition that influences the modality effect. Further evidence of the influence of element interactivity on the modality effect, is provided by a meta-analysis conducted by Ginns (2005). He reviewed the results of forty-three independent studies that investigated modality effects across a range of instructional materials, age groups and learning outcomes. Ginns (2005) meta-analysis identified the instructional benefits' of presenting words in an auditory modality when presenting information represented by words and pictures. His work also provided evidence of two conditions that influence modality effects, element interactivity and self-pacing. As previously described, element interactivity concerns the difficulty of the instructional content presented to learners. High element interactivity places a high intrinsic cognitive load upon learners while the presentation of low element interactivity instructional materials does not (Sweller, 2010). Ginns (2005) meta-analysis demonstrated that modality effects are larger when element interactivity is high and, conversely, modality effects are less when element interactivity is low. The cognitive explanation for this is that under high element interactivity conditions the presentation of verbal information associated with an image in an auditory modality acts to effectively reduce the cognitive load by spreading the cognitive load across both the visual and auditory cognitive processing channels, effectively expanding the processing capacity of the short-term memory. In low element interactivity conditions modality effects were not observed, as the visual processing channel is not overloaded (Moreno, 2006; Ginns, 2005; Mayer, 2005, 2014). The second condition that influenced modality effects identified by Ginns (2005) meta-analysis was self-pacing. Self-pacing concerns the ability of learners to dictate the pace of instruction. Ginns (2005) identified that the modality principle holds when learners cannot control the pace of instruction. Moreno (2006) attributes this to the fact that under self-paced conditions learners are able to pause and take the time they require to make referential connections (Paivio, 1986) between visually presented text and illustrations, and in cases where verbal information is presented as auditory narrations learners, are able to rewind and replay sections of the presentation, providing the time required to connect associated verbal and non-verbal information.

In research conducted by Tabbers, Martens, & van Merrienboer, (2004) learners were presented with verbal information in the form of pictures and written words in self-paced multimedia lessons. Their results identified that modality effects were reduced and even reversed under conditions in which learners were able to control the pace of instruction. More recent research by Crooks, Cheon, Inan, Ari and Flores (2012) also supports the proposition that the ability of learners to self-pace when engaging with multimedia DLOs can influence modality effects. Inan, Crooks, Cheon, Ari, Flores, Kurucay and Paniukov (2015) randomly assigned 151 undergraduate students to one of two variants of a DLO providing instruction on articulation in human speech. Each variant presented participants identical instructional messages. One variant presented information in the form of an illustration and associated on-screen text. The second DLO variant presented identical information using the same illustration but with verbal information presented as spoken text. The results showed a reverse modality effect. That is, learning was superior under written, rather than spoken text, conditions. Crooks, Cheon, Inan, Ari, & Flores (2012) conducted a similar experiment also using a DLO that provided instruction in speech articulation. These researchers found that learners studying from a DLO variant that presented information as written text and a related illustration outperformed learners who used a DLO variant that presented identical information as spoken text and an illustration. Both of these experiments required learners to recall spatial information, that is, associate verbal information with specific spatial locations on an illustration. Consequently, Inan et al. (2015) propose spatial learning as a factor that may influence the modality effect. These authors identified a lack of research in this area and call for more research to be conducted. The illustration below (Figure 4) depicts the proposed mechanism for the modality effect. The grey coloured boxes indicate cognitive load.

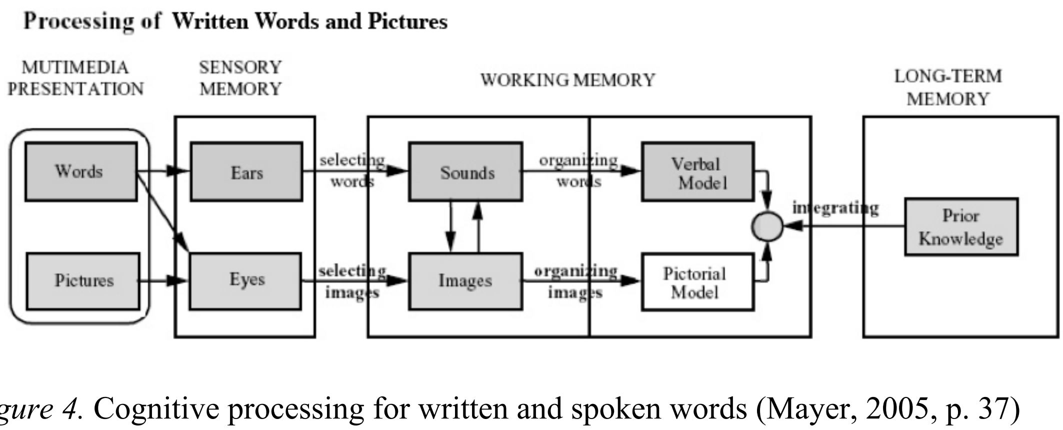

Figure 4. Cognitive processing for written and spoken words (Mayer, 2005, p. 37)

As depicted in the illustration, when pictures are presented simultaneously with written words a cognitive load is in both visual and auditory sensory memory and the associated verbal and non-verbal cognitive processing components of the working (short-term) memory. Kalyuga, Chandler and Sweller (2000) were the first researchers to report reverse modality effects. Kalyuga et al. (2000) conducted two experiments investigating the role of prior knowledge as a boundary condition of the modality effect. The results of their experiments showed that when learners possessed high prior knowledge the modality effect was reversed. In their first experiment, novice trade apprentices were presented with one of four alternative DLOs providing (identical) instruction on a drill's cutting speed graph. The DLOs presented information in the following modalities: a diagram with visual text, a diagram with auditory text, a diagram with both visual and auditory text, and the diagram alone. In recall tests participants who used the diagram plus auditory text outperformed those who used the visual only DLO variants and the diagram-only variant. In the second experiment the same group of novice trade appendices were assigned to different DLO variant groups but only after having received prior training in the topic of instruction presented by the DLOs. Under these conditions the diagram only group out performed the auditory and visual text groups, thus identifying that high prior knowledge acted to reverse modality effects. Kalyuga et al. (2000) concluded that after additional training the cognitive advantage of presenting auditory text disappeared due to redundancy of the information presented as auditory text. In other words, the participants possessed enough knowledge to understand the diagram alone with no verbal explanations of the diagram, either written or spoken, required. Kalyuga et al. (2000) called this effect 'expertise reversal' and attribute a cognitive element interactivity mechanism for the effect when associated with learners existing knowledge. According to these authors, the working memory is limited in the number of interacting elements it can process at any given time. On the other hand, the long-term memory can hold an unlimited number of interacting elements organised as schema – mental hierarchal representations of specific knowledge which are treated as a single element when being recalled and processed.

2.3.1 A cognitive mechanism for the modality effect

Mayer (2005, 2014) and Moreno (2006) propose a cognitive mechanism for the modality effect. A cognitive explanation argues that presenting information in a single visual modality (as written text and pictures) overloads the visual channel located in the working memory. This imposes an extraneous cognitive load on learners to the detriment of their learning. The modality principle proposes that the simultaneous presentation of information in dual visual and auditory modes reduces the extraneous cognitive load experienced by learners by spreading the cognitive load across both channels, effectively expanding the processing capacity of the working memory.

2.3.2 A perceptual mechanism for the modality effect

Some recent research findings challenge cognitive explanations for the modality effect (Crooks, Cheon, Inan, Ari & Flores, 2012; Rummer, Schweppe, Furstenberg, Schieter & Zindler, 2011; Rummer, Schweppe, Furstenberg, Seufert, & Brunken, 2010). These authors propose a perceptual resources explanation for modality effects. Arguments against cognitive explanations are based upon tensions between Baddeley's (1986) working memory model and CTML with respect to how learners process written text. According to CTML, the visual sensory input channel is linked to the visual cognitive processor and the auditory sensory input channel is linked to the auditory cognitive processor. This is the dual channel assumption derived from DCT (Paivio, 1986). From a CTML perspective, visual text competes with visual images for cognitive resources as both are sensed and processed via the single visual sensory cognitive channel. However, according to Baddeley's (1986) working memory model, visual text is not restricted to the visual channel. According to this model, all words, both written and spoken, are processed in the phonological loop that is analogous to the auditory channel. According to Baddeley (1986), phonological processing does not consume resources from the visual processing channel. As such, a perceptual explanation for modality effects is not consistent with cognitive explanations as proposed by CTML and CLT. A perceptual explanation argues that limitations at the visual sensory perceptual level are responsible for modality effects. In other words, if visual information is too transient in nature or complex, requiring learners to search for and associate many written words and images, modality effects arise (Crooks, Cheon, Inan, Ari & Flores, 2012).

The picture that emerges from the literature is that the modality effect is not a unitary phenomenon. The effect appears to be caused and moderated by a range of mechanisms. According to Inan et al. (2015) there is a lack of clarity in regarding the mechanisms responsible for the modality effect and the conditions that influence it. As such, there is a lack of clear guidance for people creating DLOs regarding modality and reverse modality effects.

2.4 Other multimedia design principles

CTML research has yielded further multimedia design principles relevant to DLO design. As with the modality principle, these multimedia design principles act to either increase germane cognitive load or decrease extraneous cognitive load and consequently affect learning performance. As such, the multimedia design principles of CTML may be applied as evidenced based guidelines for the design of DLOs.

2.4.1 Principle of spatial contiguity

The spatial contiguity principle identifies that learning performance is improved when corresponding pictures and visual text of an instructional message are close together rather than far apart. Experiments conducted by Mayer & Anderson (1991), Mayer (1989), Mayer & Gallini (1990), empirically identified this improvement in performance. Instructional messages presented as visual text and illustrations require learners to attend to and relate two instructional items, both of which are sensed visually, entering the learners' short-term memory via the visual channel. If the visual text and associated pictures are not located physically close together (low spatial contiguity) the learner is forced to visually scan the content of the instructional message, reading the visual text, looking at the picture and then deciding which given piece of visual text is associated with which specific illustrative item. This disrupts cognitive processing and information acquisition, as the learner has to spend time locating and associating spatially distant yet instructionally related items. Presenting related visual text and illustrations close together (high spatial contiguity) allows for more efficient visual sensing (representational processing) and more efficient cognitive processing (associative and referential processing) of information consisting of conceptually related visual text and pictures. Understanding the principle of spatial contiguity is important for people creating DLOs by informing DLO graphic design decisions that support learning.

2.4.2 Principle of temporal contiguity

According to the principle of temporal contiguity, the simultaneous presentation of the auditory and visual information improves learning compared to the non-simultaneous presentation of the same information. In experiments conducted by Mayer & Anderson (1991) and Mayer & Anderson (1992), and Mayer (1992) learners' were presented with instructional messages as visual animations and related auditory narrations. In these experiments the narrations were provided either simultaneously with the animation (high temporal contiguity) or either before or after the animation (low temporal contiguity). The experimental results showed that learners performed better when the auditory narration was simultaneously presented with the visual animation. Presentation of the narration either before or after the animation resulted in decreased performance in recall and retention. A reason for this could be that the presentation of information of low temporal contiguity does not exploit the dual channel processing capability described by DCT. The auditory words and visual animation of the instructional message need to be mentally organised and integrated to form a coherent representation. A consequence of the non-simultaneous presentation of the auditory and visual components was that not all of the information required to build a mental representation was available simultaneously in the short-term memory. As a consequence the organising and integration of the information was less efficient than if the all of the information had been available simultaneously. In contrast the presentation of information of high temporal contiguity improves the efficiently of cognitive processing and better supports learning. Knowledge of the principle of temporal contiguity has relevance to DLO design as it identifies specific conditions under which the presentation of related visual and auditory information can act to support learning.

2.4.3 The individual differences principle

Experiments by Mayer & Gallini (1990), Butcher (2006) and Mayer (2001, 2009) presented high and low prior knowledge learners with identical multimedia instructional messages using different modalities. The results of these experiments show that low prior knowledge participants exhibited larger increases in learning performance compared with high prior knowledge participants. Mayer (2001) proposes that the reason for this is that high prior knowledge learners already possess in their long-term memory coherent mental representations of the subject domain of the instructional message. Unless the instructional message contains new information that is not part of their existing schema construct (mental representation) the existing mental representation will remain unchanged. Low prior knowledge learners exhibit lower pre-test scores and greater positive differences between pre and post-test scores with exposure to the instructional messages. The individual differences principle is important in DLO design as it identifies that the instructional content presented by a DLO needs to be at a suitable curricular level for the intended users of a DLO. If the instructional content is at too high a level learning performance is degraded due to the imposition of an inappropriate intrinsic cognitive load. Conversely, if the curricular level is too low learners may not engage with a DLO, as they already know the presented information.

2.4.4 The coherence principle

The coherence principle proposes that learning is improved when extraneous material is removed from instructional messages. Experiments conducted by Butcher (2006) in which low prior knowledge learners were presented with complex visual diagrams and detailed text identified decreases in recall and retention. In the study, the presentation of simplified learning materials to low prior knowledge learners resulted in improvements in their learning performance compared to their learning performance after the presentation of more complex learning materials. The presentation of more information than is required for understanding imposes an extraneous cognitive load upon learners as they seek to identify the information they require for understanding. This results in inefficient cognitive processing as the learner is cognitively split between attending to instructional and non-instructional information. With the presentation of extraneous material the learner is forced to spend time attending to and cognitively processing information only to realise that it is not relevant. Another danger in the presentation of irrelevant content in instructional messages is that the learner may mistakenly believe that such content is relevant and as a consequence begin to construct flawed metal representations based on misconceptions. The coherence principle is of relevance to DLO design as it identifies the importance of only presenting information to learners that is essential to achieving the learning outcomes. The presentation of information not required for understanding imposes an extraneous cognitive load that is detrimental to learning.

2.4.5 The redundancy principle

The redundancy principle concerns the presentation of duplicate information or information that learners already know. Research reported by Mayer (2001, 2009) identified improvements in learning performance when learners were exposed to a DLO that presented them with information in which duplicated material had been removed. By contrast, learners exposed to a DLO that presented information containing duplicate material exhibited reductions in learning performance. Redundancy disrupts learning as it imposes an extra cognitive load upon learners who are required to sense and then cognitively process information only to conclude that the content is a repetition of previously sensed and processed content. This is an inefficient use of cognitive resources. The implication of the redundancy principle for DLO design is that for a DLO to support learning duplicate information should be removed.

2.4.6 The segmenting principle

The segmenting principle proposes that people learn better from multimedia DLOs when learners control the pace of instruction. Research presented by Mayer (2001, 2009) empirically supports this principle. Mayer (2005, 2014) argues that giving learners control over the pace of instruction allows them the time required to actively engage in the cognitive processing required to understand the presented material. Furthermore, providing learners control over the pace of instruction allows them to slow the pace of instruction when the complexity of the material begins to overwhelm them. This provides a mechanism for learners to control the intrinsic cognitive load imparted by the instructional material. However, contention exists in the literature regarding the learning benefits of providing learners control over the pace and sequence of instruction delivered by a DLO. Karich, Burns and Maki (2014) conducted a meta-analysis of learner control within DLO research literature. These authors reviewed eighteen distinct articles that provided twenty-nine empirical measures of the influence of learner control on learning performance. They concluded that the effect of learner control when using DLOs was almost zero and recommend that further research be conducted in this area.

2.5 Applying the principles of multimedia design

Mayer's (2005, 2014) Cognitive Theory of Multimedia Learning (CTML) and Moreno's (2006) Cognitive-Affective Theory of Learning from Media (CATLM) have yielded a number of multimedia design principles that when applied to the creation of DLOs result in DLOs that demonstrably support learning (Issa, Schuller, Santacaterina, Shapiro, Wang, Mayer & DaRosa, 2011; Issa, Mayer, Schuller, Wang, Shapiro & DaRosa, 2013). However, until relatively recently a reported limitation of multimedia learning and multimedia design research was that the empirical evidence supporting design principles had been derived from experiments conducted by psychologists in laboratory settings and not in authentic learning environments (Moreno, 2006; Issa et al 2011). Furthermore, other than in the field of medical education, there is a paucity of literature concerning the application of the evidenced based principles of multimedia design in education. According to Levinson (2010), Mayer has repeatedly demonstrated that applying the multimedia design principles arising from the CTML has an impressive and consistent effect on learning as measured by retention and transfer tests under laboratory-like experimental settings. Levinson observes that there has been little replication or extension of Mayer's findings in real-world settings. In a meta-analysis of Internet based learning Dupras, Erwin, Cook, Garside, Montori and Levinson (2008) found very few studies that reported the evidenced based instructional design principles used to guide the development of DLOs. These authors called for further research to investigate the effectiveness of multimedia design principles derived from the CTML in authentic learning settings. In response, Issa et al. (2011) conducted research investigating the learning benefits of the application of multimedia design principles in an authentic learning context. Year 3 medical students were provided face-to face instruction that utilised PowerPoint slides. One hundred and twenty two Year 3 medical students were divided into three groups with one group exposed to the lecture and the traditionally designed PowerPoint slides. The second group experienced the identical lecture but the slides used to support the lecture were designed according to multimedia design principles derived from Mayer's CTML. The third group was the control group and received no instruction. All three groups undertook a pre and post-test that measured recall of information delivered in the lecture. The results of this investigation identified that students who were exposed to the slides designed according to multimedia design principles demonstrated improved short-term recall compared to students who experienced the traditional slides that were not designed in accordance with the multimedia design principles. The researchers identified that further work was required to determine the affects of multimedia design on long-term recall, transfer (correctly applying knowledge to other contexts) and affects arising from using other forms of multimedia learning objects (DLOs). A subsequent experiment conducted by Issa et al. (2013) employed a similar methodology to the previously describe research (Issa et al. 2011) but investigated long-term learning effects. Using a pre-test/post-test experimental design, thirty-seven Year 3 medical students received a traditional bullet point based PowerPoint presentation as part of a face-to-face lecture on shock. Another group of forty-three students received an identical lecture but were presented Power-Point slides that had been designed using multimedia design principles derived from Mayer's CTML. The findings of this research showed that learners exposed to the slides designed according to multimedia design principles outperformed the traditional design group in recall, retention and transfer tests. The researchers recommend that medical educators learn about and apply multimedia design principles in the creation of learning materials such as PowerPoint presentations.

2.6 DLOs and the affective characteristics of learners

Kim, Kim and Whang (2013), Mayer (2014) and Moreno (2006) all propose that identified discrepancies in the results and findings of existing multimedia learning research are the consequence of the influence of affective characteristics of individual learners upon their cognitive processes. Affective characteristics are the beliefs, expectations, interests, and motivations of individual learners. Kim, Kim and Whang (2013) propose a framework of multimedia learning that extends the Cognitive Theory of Multimedia Learning, proposing that the beliefs, expectations, interests and motivations (affection) of individual learners influence their cognitive processes. Mayer (2014) supports the proposition that a learner's motivation influences engagement in the cognitive processes of selecting, organising and integrating information sensed from multimedia. The proposition is further supported by Moreno's (2006) Cognitive-affective Theory of Learning from Media (CATLM) that proposes that affective characteristics (motivation, beliefs, emotions and expectations) of the learners influences learning. Mayer (2014) observes that motivational and other affective factors have not been the focus of multimedia and cognitive load research. This view is reinforced by Brunken, Plass and Moreno (2010) who state,

> Although it is well known that metacognitive, affective and motivational constructs are central to learning, they have not been the focus of cognitive load research …Therefore, there is great potential to test specific hypotheses about the relation among motivation, cognition, cognitive load and learning Brunken, Plass and Moreno (2010, p. 262).

Mayer (2014) also proposes that the affective features of a multimedia instructional message presented by a DLO can influence the level of learner engagement in cognitive processing during learning. This proposition is supported by the emotional design hypothesis reported by Plass, Heidig, Hayward, Homer and Um (2013). Plass et al. (2013) were able to show that incorporating emotionally pleasing graphic designs improved learner performance on comprehension tests and self-ratings of motivation. Further research by Magner, Schwonke, Alevev, Popescu and Renktl (2013) showed that the emotional design effect is only demonstrated when the emotionally pleasing design element was relevant to the instructional content. Adding pleasing emotional graphic DLO design elements irrelevant to instruction did not result in improved learner performance however learners still self-reported high levels of motivation. Taken as a whole these studies identify that the emotions of learners can be influenced by DLO multimedia design choices which in turn may influence learning and perceptions of learning.

2.7 Conclusion

The reviewed literature supports the proposition that DLO multimedia design features such as information presentation modality can positively or negatively affect learning. Furthermore, the literature identifies that design features also affect learners perceptions of learning and the emotions of learners. According to Churchill (2014) there is a lack of empirically informed guidelines on how to design digital learning objects. Although the cognitive theory of multimedia learning provides empirically developed principles for the design and use of multimedia materials for learning and teaching, these principles have not been explicitly connected with the DLO design literature (Churchill, 2014). Historically, research about learning with digital technologies has been conducted in the separate and siloed domains of psychology, technology and education. However, there is increasing convergence of these research strands and a coherent, unified discipline concerning the application of multimedia learning principles to the creation of DLOs is emerging.

Chapter 3 Methodology

3.1 Introduction

This chapter provides a description of the methodology used in this research. An overview of the participants and setting, data collection methods and analysis, discussion of the validity, reliability of the research methodology and ethical considerations are provided. This research employed two phases, a design phase and an experimental phase. Each phase had unique aims and utilized distinct methodologies involving the collection and analysis of data. The design phase and the experimental phase are considered separately.

3.2 Case study methodology

A case study methodology was selected for this research and the results are presented as three separate case studies, one for each of three DLO variants. According to Altrichter (2008, pg. 229), case studies are 'written reports in which practitioners present information about one case taken from their practice, including the context and starting point, research methods, the stages of the research, findings, proposed action strategies, and emerging issues that may be the subject of further work.' The context of the three cases was investigation into the effects of DLO design on learning and perceptions of learning. The creation of the forces of flight digital learning object variants was the starting point of each case study and a variety of research methods were used to investigate relationships between learning and perceptions of learning and DLO properties. The findings of this research and suggestions for further research are presented later. According to Stake (p.156, 2003), a case study is "of value for refining theory and suggesting complexities for further investigation, as well as helping to establish the limits of generalizability". This research sought to identify the limits of generalizability and complexities of CTML and highlight areas for future research.

There were several reasons for employing case study research methodology in this study. One was that the researcher's experience designing and creating learning objects while working as an e-learning instructional designer. Working in this capacity the researcher observed a knowledge gap amongst many instructional designers and teachers regarding the influence of DLO design upon learning and perceptions of learning. Another reason a case study methodology was selected was because of the low number of research participants. Low participant numbers made the statistical analysis of pre-post assessment results statistically unreliable.

3.2.1 A mixed methods approach

A mixed methods methodology was selected as the research method for each of the three case studies. Kay and Knaach (2007, 2009) meta-analysis of the learning object evaluation literature supports the choice of a mixed methods approach. They identified the use of wholly quantitative or qualitative approaches as the norm but also saw this as a limitation. According to Kay and Knaach (2007, 2009), digital learning object evaluation research historically has offered qualitative and anecdotal evaluations and lacked the use of formal statistics to evaluate learning performance. They therefore encourage the use of mixed methods approaches when evaluating DLOs in order to advance understanding of the features of digital learning objects that may affect learning. For this reason a mixed methods approach was selected for this research.

Mixed methods research designs combine qualitative and quantitative methodologies by gathering and analysing quantitative and qualitative data in a single study (Gay, Mills & Airasian, 2006). In this research a pre/post assessment and a user perception survey (UPS) provided quantitative data while participant interviews collected qualitative data. Mixed methods research methodology exploits the synergies that exist between qualitative and quantitative research methods and is a research approach which enables a deeper understanding of the phenomenon being investigated than is possible using either a quantitative or qualitative methods alone. (Castro, Kellison, Boyd and Kopak, 2010). In this research the interview data provided insights into the relationships between DLO properties, learning and perceptions of learning that would not have been possible using UPS and pre/post assessment results alone. Furthermore, data obtained from a range of different sources using a range of different data gathering tools allows for the triangulation of data which supports data validity and reliability (Castro, Kellison, Boyd and Kopak, 2010; Gay, Mills & Airasian, 2006). Gathering data from multiple sources facilitates the validation of data by cross verification. This is called triangulation and supports data validity. Validity is the degree to which a data gathering instrument, in this case the pre and post-test, UPS and interviews measure what they are supposed to measure (Castro, Kellison, Boyd and Kopak, 2010; Gay, Mills & Airasian, 2006).

Quantitative

The type of quantitative method used in this research is causal as it seeks to answer questions through the observation of effects on the dependent variables (pre/post test scores and user perception survey responses) arising from the manipulation of the independent variable, DLO design (Gay, Mills & Airasian, 2006). Experimental research investigates the causal relationships between a dependent and an independent variable. Clark-Carter (p5, 2009) states ‘the main distinction of experimental methods is that researchers manipulate certain aspects of the situation and measure the presumed effects of those manipulations’. In this study the independent variable is the DLO design and the dependent variable is learning efficacy, as represented by differences in pre and post intervention test scores. Quantitative research is deductive, involving the collection and analysis of numerical data in order to test hypotheses and determine relationships between variables (Gay, Mills & Airasian, 2006).

Qualitative

Mixed methods research designs also use qualitative methods. Jackson, Drummond and Camara (2007) state that qualitative research is concerned with understanding human beings experiences in a humanistic, interpretive approach. According to Gay, Mills & Airasian (p6, 2006), qualitative research involves the collection, analysis, and interpretation of comprehensive narrative, visual and other non-numerical data in an endeavour to gain insights into a particular phenomenon of interest.’ According to Teddlie & Tashakkori (p.23 2009), qualitative research methodologies explore “the properties of a phenomenon or the possible relationships between variables”. In this research qualitative data was collected by online survey and face-to-face interviews that revealed participant perceptions of learning arising from the use of a specific DLO variant. Perception is challenging to quantify and a qualitative approach provides a richer picture of the dynamics at play and a rich data set that complements the quantitative pre-post-test data.

3.3 The design phase

The aim of the design phase was to check the suitability of the instructional messages delivered via the Forces in Flight DLO, test the usability of the DLO variants used in the experimental phase and to appraise the appropriateness of the questions used in the pre-post assessment employed as data gathering instruments in the experimental phase.

3.3.1 Development of the forces of flight DLO

How was the DLO chosen?

The concept of forces was chosen as a suitable theme for the DLO used in this research. The reason for selecting this topic was the identification by the research supervisors that the intended research participants (year 1 and 2 primary teacher trainees) generally have little knowledge of the concept of forces. The rationale for the selection of a concept which potential participants had little existing knowledge of was to ensure that participants had the opportunity to learn. In other words, if participants already knew the subject matter then there would be little opportunity for them to exhibit new learning. The instructional level of the science concept presented by the DLO was level 1-4 in the Physical World strand of the New Zealand science curriculum (Ministry of Education, 2007). This was chosen because graduate primary and intermediate schoolteachers are expected to teach at these curriculum levels. Upon identification of the subject and the curriculum level, the researcher conducted an Internet search using the key words “science”, “learning objects” and “New Zealand”. The search returned the New Zealand Science Learning Hub (www.sciencelearn.org.nz). The Science Learning Hub was developed by New Zealand educators and teachers in collaboration with New Zealand scientists to provide resources for teachers of students up to Year ten. The site is funded by the

Ministry of Business, Innovation and Employment and is managed by the University of Waikato. The Science Learning Hub was chosen as a source of a DLO to be adapted for the purposes of this research as it is accessible to New Zealand primary school teachers seeking foundation science learning objects. Searching on the word "forces" on the Science Learning Hub website returned a reference to science ideas and concepts about the principles of flight. Published on the web page (http://sciencelearn.org.nz/Contexts/Flight/Science-Ideas-and-Concepts/Principles-of-flight) was a simple graphical digital learning object that presented the names of the four forces of flight each spatially co-located with an arrow indicating the direction of operation of any given force (Figure 5). This DLO was selected as its instructional content was about forces in the context of flight; it was at the targeted curriculum level and the researcher identified that the existing resource could be easily modified for the purposes of this research. The researcher sought and received permission from the Science Learning Hub to adapt this resource for use in this research.

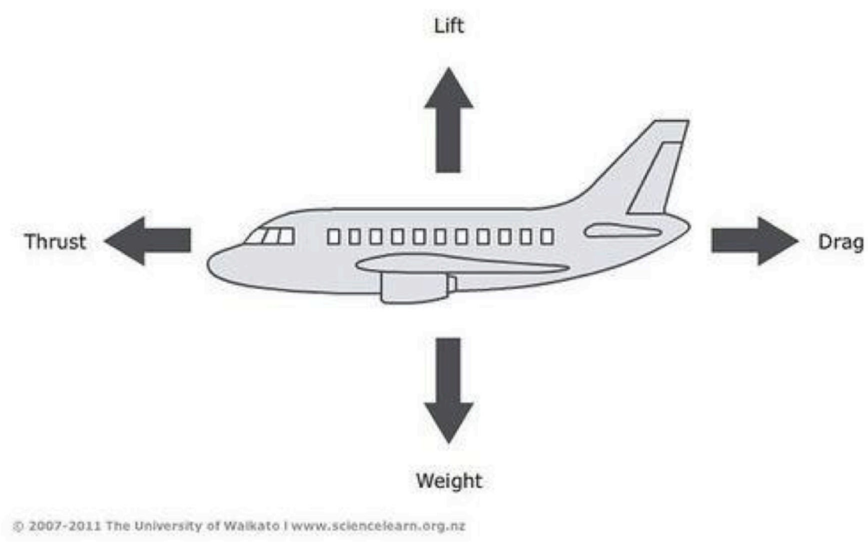

Figure 5. Original forces of flight DLO (Science Learning Hub, The University of Waikato. www.sciencelearn.org.nz, 2011)

Adaption of the original forces of flight DLO

Adaptation of the Science Learning Hub's forces of flight DLO created all variants of the forces of flight DLO. The animation software Adobe Flash CS6 © was used to author three variants (Figure 6) that were published as interactive animations to the University of Canterbury's learning management system (Learn).

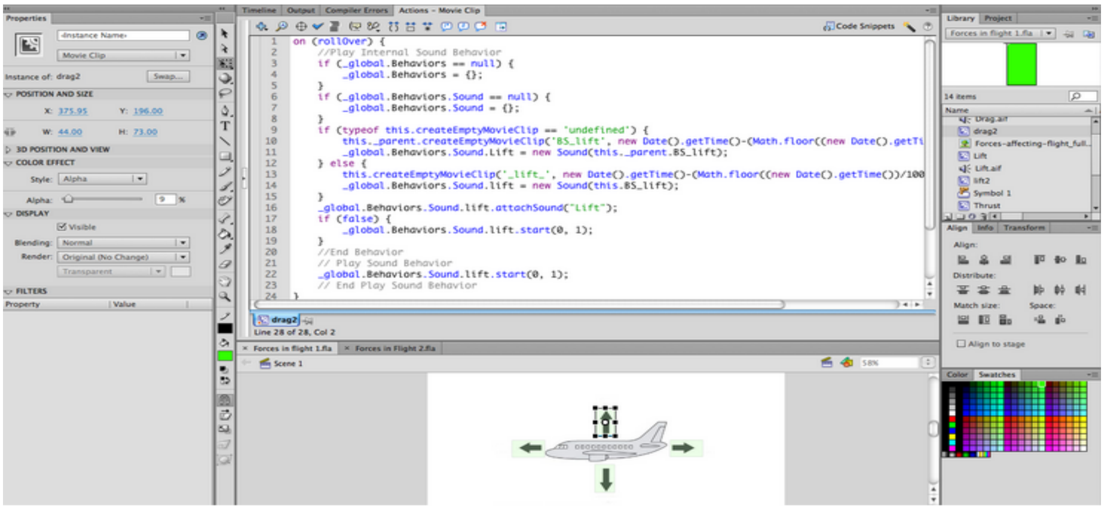

Figure 6. The DLO authoring environment

Each variant presented users with an incomplete pictorial representation indicating the direction of operation of each of the four forces that act upon an aircraft in flight.

Force names were disassociated from their respective force direction arrows and positioned on the left hand side of the DLO. The researcher used Adobe Flash CS6 © to make the force names interactive. Using a computer mouse, participants could click the left mouse button on a force name and drag the force name around the screen. Releasing the left mouse button allowed users to "drop" the force name on one of four visual arrows indicating the direction in which each force acts (Figure 7). This type of interactivity is commonly called "drag and drop". When a force name was correctly associated with a force direction arrow the force name "stuck" to the arrow. If the matching of a force name and force direction arrow was incorrect the force name automatically returned to its starting position. The drag and drop interaction allowed users to actively construct a complete pictorial representation which identified the names and direction of operation of each of the four forces which act upon an aircraft in flight.

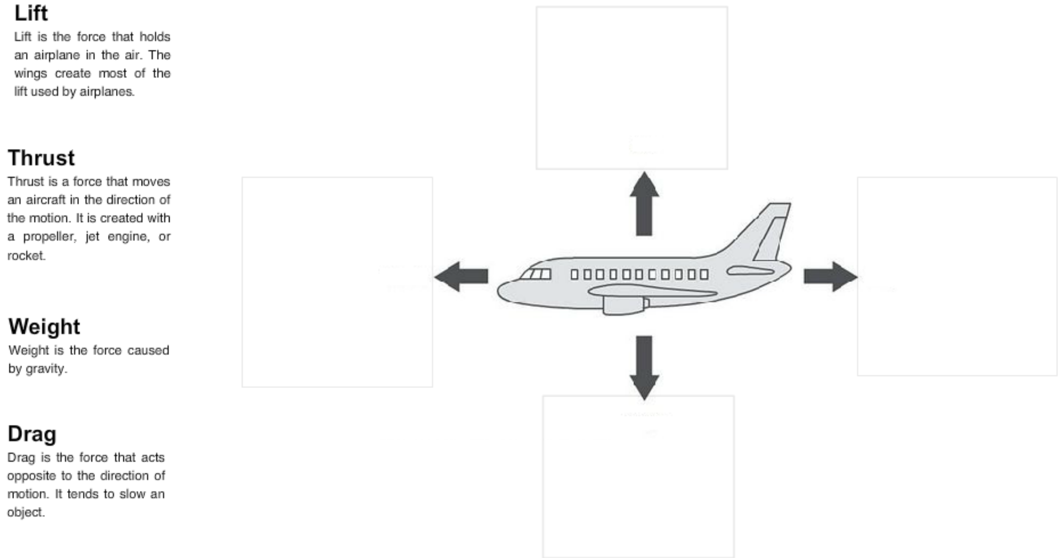

Figure 7. Visual variant of the forces of flight DLO. Instructional messages are shown on the left.

Additional instructional messages

Each DLO variant presented users with additional instructional messages describing a property of each of the four forces involved in flight. These instructional messages were presented in one of three different sensory modalities, visual, auditory, and combined visual and auditory. The instructional messages were identical for each variant, with each variant being distinguished only by the sensory modality of its instructional messages. Instructional messages were spatially co-located with the appropriate force name.

The three DLO variants created were:

1. Visual variant – the instructional messages were presented as visual text.
2. Audio variant – the instructional messages were presented as auditory text.
3. Audio-visual variant – the instructional messages were presented simultaneously as visual and auditory text

The researcher used the audio recording software Apple Logic Pro X © to narrate the auditory instructional messages. The audio files were saved in the mp3 file format and imported to the Adobe Flash CS6 © authoring application for inclusion in the DLO. Visual instructional messages were created within the DLO authoring environment Adobe Flash CS6.

The instructional messages were:

1. The direction of the lift force is up. Lift is the force that holds an airplane in the air. The wings create most of the lift used by airplanes.
2. The direction of the drag force is opposite to the direction of motion. It tends to slow an object. Drag is caused by friction and differences in air pressure. An example is putting your hand out of a moving car window and feeling it pull back.
3. The direction of the thrust force is in the direction of the motion. It is created with a propeller, jet engine, or rocket. Air is pulled in and then pushed out in an opposite direction. One example is a household fan.
4. The direction of the weight force is downwards. The weight force is caused by gravity.

3.3.2 Design phase participants

There were seven participants in the design phase. Potential participants were identified by the researcher and invited to participate via email. Design phase participants included two teachers, two instructional designers and three students. Design phase participants did not take part in the experimental phase of this research.

3.3.3 Design phase data collection

An online survey was used to gather design phase participants feedback on the usability of the DLO variants, the quality and quantity of the instructional messages presented by the DLO and to gauge the choice of the questions used in the pre/post assessment. The survey was published on the University of Canterbury's Moodle (Learn) learning management system (LMS) using the LMS's Feedback activity. The survey questions were:

1. What did you like about the forces in flight DLO?
2. How could the forces in flight learning object be improved?
3. For you, was the instructional level of the forces in flight learning object; too easy, just right, too hard?
4. Did you find the quiz questions: too easy, just right, too hard?

3.4 The experimental phase

In the experimental phase the DLO variants created during the design phase were presented to the research participants.

3.4.1 Research phase participants

Research participants were drawn from early childhood, first and second year trainee primary teachers and first year statistics students studying at the University of Canterbury. This participant group was selected as the researcher was based at the University of Canterbury and had access to these groups of potential participants. Furthermore, it was thought that members of this group would be unlikely to have extensive prior knowledge about the forces associated with flight.

Enlisting research phase participants

The researcher enlisted participants by two methods:

- Face to face call for volunteers at the end of regular scheduled classes. The researcher made three separate requests for participation.
- A call for participation via a video clip created by the researcher and published to two online courses hosted on the University of Canterbury's Learn Learning Management System.

Consent forms and information letters were available at the face-to-face lectures and within the online courses. Consent forms were signed and returned to the researcher. Alternatively, participants completed the online consent form.

Allocation of participants to groups

Participants were randomly assigned to one of three groups. Each group had access to a variant of the Forces of Flight DLO. The three groups were:

- Visual – participants assigned to the visual variant.
- Audio – participants assigned to the auditory variant.
- Audio-visual – participants assigned to the audio-visual variant.

The group functionality of the Moodle learning management system was used to restrict participant access only to the variant to which their group was assigned.

Participant activity

Research participants were required to:

- Complete the pre assessment. This was an online quiz consisting of thirteen questions with a possible maximum score of thirteen marks. Participants were permitted only one attempt and there was no time limit placed on the attempt.
- Engage with the Forces in Flight learning object for at least 5 to 10 minutes over a three-week period. This period of engagement was selected as the literature indicates this to be the minimum amount of time that a new concept needs to be engaged with by low prior knowledge students for learning to occur (Church, 1999).
- Complete the post assessment. The post-assessment was identical to the pre-assessment.
- Complete a User Perception Survey (UPS)

3.4.2 Data collection

All participant activity was conducted online via the University of Canterbury's Learning Management System (Learn). This required participants to have access to an Internet connected computer with audio-visual capabilities. This enabled participants to engage with the research activity at a time and place of their choosing.

Four data collection instruments were used. These were:

1. Online quiz (before and after interacting with the DLO)
2. User Perception Survey

3. One to one interviews

The pre-post assessment and the User Perception Survey gathered quantitative data while the one to one interviews gathered qualitative data. The pre-post assessments were constructed and conducted using the Learn Learning Management System (LMS) quiz engine and the user perception survey (UPS) was created and conducted using the Learn feedback tool.

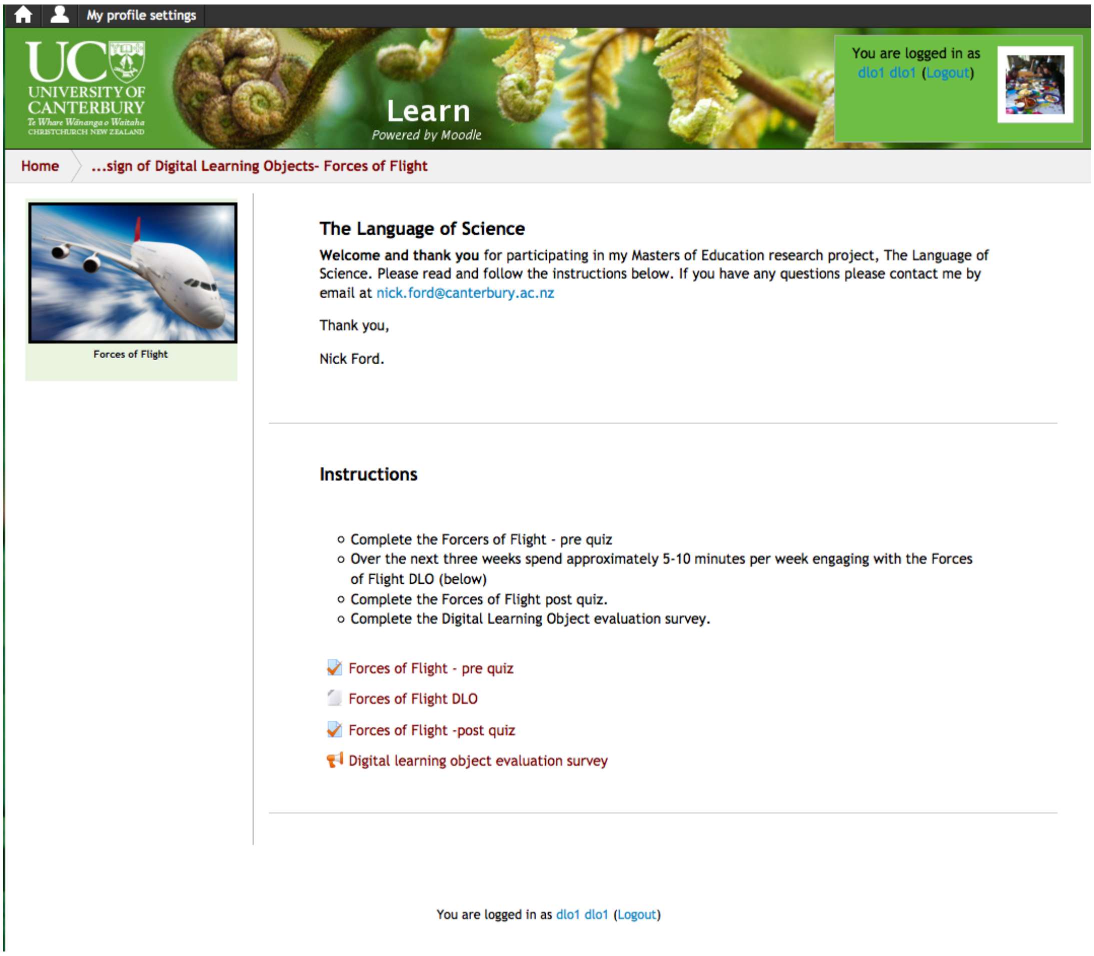

Figure 8. Screenshot of the research website

Information regarding the project and the DLO was located within a Learn site that participants were given access to. The Learn site (Figure 8) contained:

- A welcome message for participants

- Instructions for participants
- The pre and post assessments
- The Forces in Flight DLO (one of three variants)
- The Forces in Flight user perception survey (UPS)

3.4.3 Pre and post assessment

Results gathered via the assessment were intended to provide data about changes in learning performance. The use of pre-post assessment to gather quantitative data for the purpose of determining learning efficacy arising from the use of digital learning objects is well documented in the literature (Mayer, 2001, 2005, 2009, 2014; Sweller, 2005). The pre/post assessment consisted of thirteen questions presented as online Learn learning management system quizzes (Figure 9). Pre-post assessment questions were derived from the information presented by the forces of flight DLO. The DLO was not displayed when participants were answering the questions. The pre-post assessment questions were:

1. What is the direction of the drag force?
2. What is the direction of the lift force?
3. What is the direction of the thrust force?
4. What is the direction of the weight force?
5. What is the name of the force caused by gravity?
6. When you put your hand out of the window of a moving car and feel it pulled back you are feeling this force. What is its name?
7. What is the name of the force created by the wings of an airplane?
8. What is the name of the force that acts to slow an airplane down?

9. Predict what would happen to an airplane if the drag force were greater than the thrust force.

10. Predict what would happen to an airplane if the weight force were greater than the lift force.

11. Identify the two forces that enable a plane to take off?

12. Identify which two forces need to be reduced when landing a plane?

13. Identify which two forces could cause a plane to stall

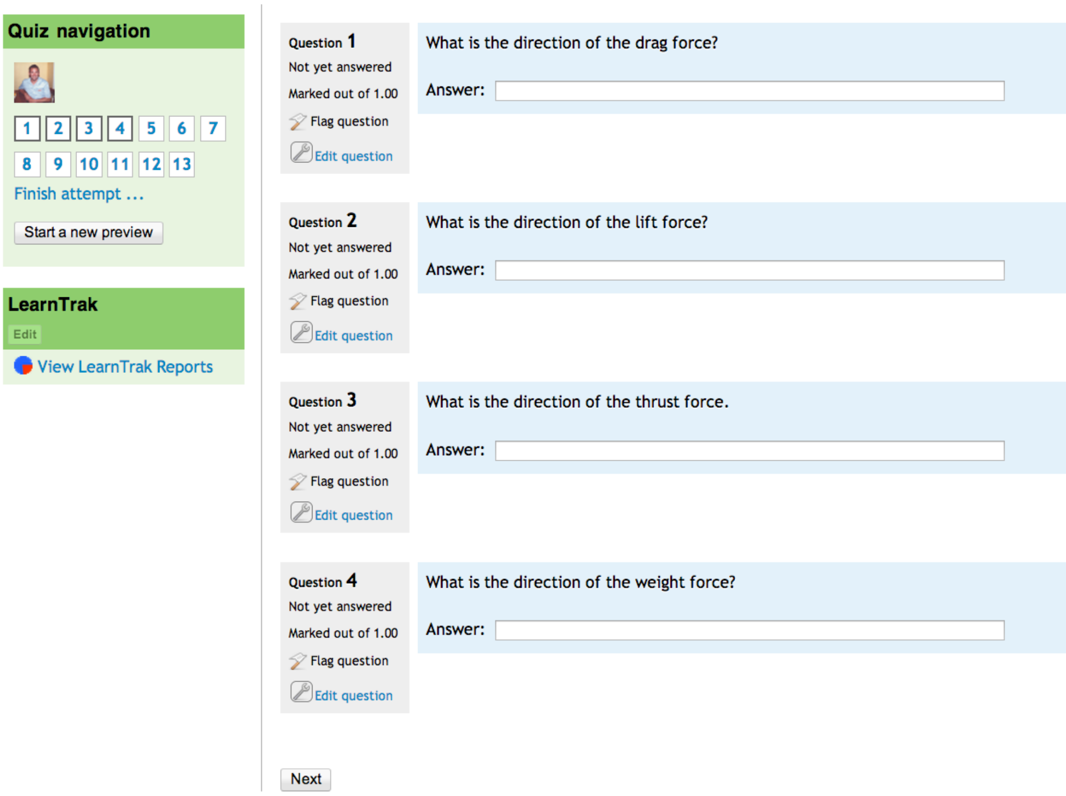

Figure 9. The online pre and post assessment

3.4.4 The user perception survey (UPS)

Qualitative data about the participants' perceptions of the Forces of Flight DLO variant were gathered via the online User Perception Survey (UPS) (see Appendix 4). The use of surveys for the gathering of learning object user perception is well documented in the literature (Schibeci, Lake, Phillips, Lowe, Cummings and Miller, 2008; Kay, 2011, 2012; Kay and Knaach, 2007, 2009). The aim of the UPS was to validate the data obtained from the pre/post-assessment and the one to one interviews. Questions used in the UPS were taken from the evaluating learning, design, and engagement dimensions of the Web-Based Learning Tools (WBLT) evaluation scale (Kay, 2011, 2012). The WBLT evaluation scale was selected as it provides a contemporary research based learning object evaluation methodology. Derived from a thorough meta-analysis of the learning object evaluation literature, the WBLT evaluation scale addresses many of the limitations identified in the literature (Kay and Knaach, 2007. 2009). Responses to WBLT evaluation scale items are indicated via a five point Likert scale with 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

The questions used in the UPS were grouped according to theme. The themes were, learning, engagement, design and demographics. The questions were:

Learning

1. Working with the learning object has helped me learn.
2. The interactivity of the learning object helped me learn.
3. The multimedia properties of the learning object helped me learn.

Design

4. The instructions in the learning object were easy to follow.
5. The learning object was easy to use.

6. The learning object was well organized.

Engagement

7. I liked the overall theme of the learning object.
8. I found the learning object engaging.
9. The learning object made learning fun.
10. I would like to use this learning object again.

Demographics

11. What is your age? (a free text response)
12. Identify your gender M/F (multi choice response)
13. I am confident using information and communication technologies (multi choice response using Likert scale identified above)

3.4.5 Interviews

One to one interviews were conducted with two participants from each variant group. Interview participants were randomly selected and a total of seven interviews were conducted. Interviews were recorded on a portable digital recording device and transcribed by the researcher. The interviews were semi-structured with the questions used being based upon the questions used in the UPS. The semi-structured interview questions were designed to elicit participants' perspectives on the learning benefits, design features and usability of the forces-of-flight DLO and were intended to provide access to information that could not be elicited through the pre- and post-tests or the UPS. The use of interviews is common in the learning object evaluation literature (Kay, 2011, 2012; Kay and Knaach, 2007, 2009) although Kay (2012) identifies the sole use of interviews as a methodical limitation in learning object evaluation research. In the case of this research the interviews provided access to valuable data that complemented and helped explain the data gathered in the UPS and pre-post assessment.

The questions used in the interviews were:

- Has using the learning object helped you learn? Why or why not?
- Why do you think it helped you learn? Why or why not?
- Did the interactivity of the learning object help you learn? Why or why not?
- Did the multimedia properties of the digital learning object help you learn? Why or why not?
- Were the instructions about using the digital learning object easy to follow? Why or why not?
- Did you find the digital learning object easy to use? Why or why not?
- Is the digital learning object well organized? Why or why not?
- Did you find the digital learning object engaging? Why or why not?
- Did the digital learning object make learning fun? Why or why not?
- Did you like the theme of the digital learning object? Why or why not?
- What did you like about the digital learning object? Why or why not?
- What didn’t you like about the learning object? Why or why not?
- What is your definition of a digital learning object?
- As a student, do you use digital learning objects as part of your learning?
- What is your definition of learning?

3.5 Ethical considerations

Research involving human subjects requires consideration of ethical issues throughout the research lifecycle (Mutch, 2005). For this research, data was only collected after ethical approval was obtained from the University of Canterbury Educational Research Human Ethics Committee. Ethics approval was granted in May 2013. Information letters were given to all participants (Appendix 6). The information letters provided details on the purpose, conduct, and possible dissemination of the research. Before participating in this research potential participants were required to read the information letter and sign the consent form (Appendix 6). The language used in the ethics application, the consent form and the information letter was suitable for the participants. Participants were informed of their right to withdraw from the research at any time, their right to anonymity and they were provided assurance about the security of all data obtained during the research.

3.6 Limitations

The small sample size was a significant limitation of this research. The small sample size (n=13) negated the statistical analysis of the pre-post-assessment data. As such, it is not possible to make conclusions about the impact on learning or perceptions of learning for any particular DLO variant using the pre-post assessment data alone. Wilcoxon Signed Ranked tests were conducted (see Appendix 1, 2 and 3) on the pre-post assessment results but the sample sizes were so small that the results of the analysis could not be considered to be statistically valid. Consequently, the small sample size had a negative impact upon the validity and reliability of data gathered from the pre-post assessments. According to Gay, Mills & Airasian (2006), ways to address limitations imposed by small sample sizes are to either increase the sample size or replicate the research with different participants. Although the researcher advertised for participants on multiple occasions a larger sample size was not realized and time constraints prevented the replication of this research with other participants. In this research the use of pre-post assessments, survey and one-to-one interviews did provide a rich source of qualitative and quantitative data. Furthermore, the use of three data gathering instruments helped triangulate the data that was gathered. Despite the small sample size, data triangulation supported the validity of the data that was gathered. Qualitative data provided rich insights into the quantitative data gathered using the pre-post assessments. This was helpful in identifying possible underlying explanations for the results, contributing to the identification of the role of both the cognitive processes and affective characteristics of learners in learning and perceptions of learning and multimedia DLO design. As such, the case study approach contributed to the identification of further areas of future research as described in the discussion and conclusion (chapters 5 & 6). Using a case study approach was time consuming, however the approach used in this research is replicable and potentially could be applied to a wider population. Using a mixed methods approach within the case study methodology helped address the possibility of researcher bias. Interview transcripts were presented to participants for accuracy while the design phase of the research established a marking guide for the questions used in the pre-post assessments.

Chapter 4 Results

4.1 Introduction

This chapter presents the results and the analysis of these results for the design and experimental phases. Design phase results concern participants' experience with the forces of flight DLO. Design phase data was collected using an online survey and was used to inform the design of the three DLO variants and the questions used in the pre-post assessment used in the experimental phase of the research. Experimental phase results concern the participants' experiences with the three variants of the forces-of-flight DLO. Data for the experimental phase was obtained from the pre and post-tests, the user perception survey and semi-structured interview transcripts. The data is presented as three cases, with each case specific to one of the three design variants of the forces-of-flight DLO (audio, visual and audio-visual). The pre and post-assessment was used to assess participants learning performance prior to (pre-test) and after (post-test) interacting with the DLO. The pre and post-test consisted of the same thirteen questions, designed to assess participant knowledge of the forces associated with flight. The User Perception Survey (UPS) presented participants with statements about the DLO. Each of the ten statements presented in the USP related to one of three themes; learning, engagement and design (Kay, 2011; 2012). The responses available to participants were; strongly agree, agree, neutral, disagree and strongly disagree. Participant responses to each statement for each design variant of the DLO are presented in the results section for each case. In order to assist with analysis of the results, those participants taking part in the semi-structured interviews are identified by pseudonyms in the UPS results. The semi-structured interview questions were designed to elicit participants' perspectives on the learning benefits, presentation design features and usability of the forces-of-flight DLO. Participant responses to the interview questions provided access to information that could not be elicited through the pre- and post-tests or the UPS. The results from the pre and post-test, UPS and interviews were analysed in relation to the research questions;

1. How did the modality of instructional messages presented by the forces of flight digital learning object affect learning and perceptions of learning?
2. What properties of the forces of flight digital learning object did users perceive as supporting learning?

4.2 Design phase results

Design phase participant responses from the survey were;

Question 1: What did you like about the forces in flight DLO?

Responses

- *Spoken explanation as you moved your mouse over each box.*
- *It used all three learning methods, seeing, hearing reading visual and aural to enhance text.*
- *The diagram, arrangement as it left a bold visual image. The fact that you could hover over the labels for audio.*
- *The kinaesthetic analogy e.g. I could imagine feeling drag by holding my hand out of the window.*
- *Being able to work at my own speed.*
- *Being able to revisit each of the forces if required.*
- *Being able to read and hear the text simultaneously.*
- *Easy to navigate.*
- *Liked the wording and the continued use of the word force - re-emphasized the purpose.*

- *Simple explanations on what can be quite a technical subject.*
- *The visual of the plane worked well and provided a clear visual image of each of the forces in flight.*

Question 2: How could the forces in flight learning object be improved?

- *More animation. Would have been nice to see the words in action as they are spoken.*
- *Moving graphics - seeing each part of the plane moving to the specific four forces as you put your mouse over each Force.*
- *Movement in the plane.*
- *It took a moment to find the audio, so a wee instruction under the diagram about that would have been good. Use of colour. The quiz questions should have been jumbled, so you had to think harder about each question.*
- *Didn't realise that I could hear anything until I hovered over - maybe a small note to explain.*
- *More animated and interactive e.g. show the plane lifting etc.*
- *"The examples used, e.g. household fan and hand out of car do not correlate to the flight image or facts. So I found the examples given a little confusing, as they did not directly connect to flight.*
- *There were a couple of grammar errors in the questions.*
- *Without further instruction that specifically relates to "wings" and "spoilers" this question could have been too difficult to answer. I used existing knowledge to answer, rather than assimilating the new information. The question appeared remote from the focus of the lesson.*

Question 3: For you, was the instructional level of the forces in flight learning object; too easy, just right, too hard?

- All 7 participants chose “just right”.

Question 4: Did you find the Forces in Flight quiz question: too easy, just right, too hard?

- 5 participants responded with “just right”
- 1 participant responded with “too hard”
- 1 participant responded with “too easy”

4.2.1 Analysis of design phase results

Feedback gathered during the design phase (see above) identified that participants generally perceived the forces of flight DLO as usable. Consequently only minor changes were made to the learning object. Changes implemented as a consequence of design phase participant feedback included:

1. The removal of information not directly related to flight. For example, the information comparing the wing of an airplane to a spoiler of a motorcar. Corresponding questions were also removed from the pre/post-test.
2. The correction of grammatical errors.

The redesign of the DLO based upon participant feedback marked the end of the design phase. The re-designed DLO variants were then deployed in the experimental phase.

4.3 Experimental phase results

4.3.1 Case one: Visual variant

4.3.2 Participants

Four participants, Amber, Sinead, Hazel and Michael, were randomly assigned to the visual variant of the forces-of-flight DLO. All were undergraduate students at the University of Canterbury.

4.3.3 Data collection

An on-line quiz was used to assess learning performance prior to (pre-test) and after (post-test) interacting with the DLO. The on-line quiz consisted of thirteen questions designed to assess student knowledge of the forces associated with flight. Following the period of time spent interacting with the DLO participants then completed an online quiz (post-test) and the User Perception Survey (UPS). Two participants' (Hazel and Sinead) participated in a semi-structured interview.

4.3.4 Pre- and post-test scores

The pre- and post-test scores for each participant are presented in Table 2. The total score available for each test was 13 marks.

Student	**Pre-test score**	**Post-test score**	**Difference**
Amber	10.5	12.5	+ 2
Sinead	4.5	6.5	+ 2
Hazel	8.5	13	+ 4.5
Michael	9	13	+ 4
Average difference between post and pre assessment for group			+3.13

Table 2: Pre and post assessment scores for the visual variant. The differences between scores is shown

The pre- and post-test results show that all participants had higher post-test scores than pre-test scores. This suggests that use of the DLO helped all participants learn new information about the forces of flight. A high pre-test score identified participants with a high level of prior knowledge of the science concepts associated with the forces of flight.

4.3.5 User perception survey (UPS)

Following interaction with the DLO, each participant completed the User Perception Survey (UPS). Table 3 presents the results of the UPS for the visual variant group.

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Working with the learning object has helped me learn.			1	2 S	1 H
The interactivity of the learning object helped me learn.				3 S	1 H
The multimedia properties of the learning object helped me learn.			1 S	2	1 H
The instructions in the learning object were easy to follow		1 S		2	1 H
The learning object was easy to use.				3 S	1 H
The learning object was well organised.			2 S	1	1 H
I liked the overall theme of the learning object.		1 S		2 H	1
I found the learning object engaging.		1 S		3 H	
The learning object made learning fun.			1 S	3 H	
I would use the learning object again.				4 S, H	

Table 3: User perception survey for the visual variant. Responses for the two participants who were later interviewed, Sinead (S) and Hazel (H) are shown.

The UPS (Table 3) identified that the participants' perception of the visual variant of the DLO were generally positive. Three of the four participants believed that using the DLO helped them learn. These participants identified the features of the DLO that helped them learn as being the DLO's interactivity and multimedia features. Three participants perceived the DLO as engaging. UPS responses identified that these participants attributed their engagement with the DLO to; the forces of flight theme of the DLO, the fun experienced when using the DLO, the usability of the DLO, the interactivity and the multimedia aspects of the DLO. This suggests a connection between learning, engagement and design. One participant (Sinead) did not find the DLO engaging. Other survey responses by Sinead suggest that the reason she did not find the DLO engaging was because she did not like the forces theme of the DLO and she found the instructions about how to use the DLO difficult to understand. Of all the participants Sinead had the lowest pre-test score and displayed the smallest increase in post-test score (+2.5).

4.3.6 Interviews

Learning

Hazel

When asked if using the DLO helped her learn, Hazel said;

> *"Yes. I guess because I was actually interacting with it ... it was the fact that I had to click and interact .... The fact that you're moving something on the screen and there is the visual component as well as the intellectual component ... the information that you could read and yeah I quite enjoyed that."*

Hazel believed that using the DLO helped her learn. She attributed the acquisition of knowledge to her experience of interacting with the learning object, by clicking and dragging the movable force names and to reading and responding to the instructional messages. Hazel perceived that the DLO's physical interactivity combined with the visual modality of the content made it enjoyable to use. Hazel's belief is supported by the improvement in her post-test score compared to her pre-test score. In the pre-test Hazel scored 8.5 out of 13 while in the post-test she scored 13 out of 13. Hazel's responses in the UPS also support her belief.

She went on to explain;

> *"You're getting a different part of your brain involved ... that you have to make a physical movement and there is a connection between the movement and the information"*

Hazel considered that the physical interaction with the DLO helped her learn. Contemporary pedagogy acknowledges a connection between physical activity and learning. Being able to interact with and move around within a digital environment enables learning in ways that reading a book, listening to words or watching a movie do not. The pictorial representation of the forces acting on a aircraft and the physical action of dragging force names to the force direction arrows allowed participants to physically build a complete pictorial representation of the science concepts associated with the forces of flight through physical click and drag interactions.

The visual variant DLO group was presented with instructional messages associated with the image as visual text. When asked to comment on this multimedia aspect of the DLO, Hazel said;

"I read the text ... it was reading and understanding the definitions that allowed me to know which one to match it with. I didn't just grab one and put it in all four places until it stayed there ... yeah I actually engaged with it. I could tell from reading the clue where it was likely to go."

Hazel indicated that reading and comprehending the instructional messages during a drag and drop interaction, helped her correctly associate force names with the corresponding force direction arrow. She considered this to be a more successful strategy than simply guessing which force name belonged with which force direction arrow. This suggests Hazel believed that the visual instructional messages contained clues that assisted her in learning to respond correctly in the drag and drop activity. This is supported by Hazel's response in the UPS as she strongly agreed with the statement 'the multimedia features of the learning object helped me learn' (Table 3).

Sinead

When asked if using the learning object helped her learn, Sinead replied;

"Yes .... It taught me stuff about forces ..... I liked the pre-quiz then learning then having the opportunity to redo it... the pre-quiz was hard but only because I didn't know any answers and I did okay in the post-quiz."

Sinead felt that the DLO helped her to learn about the science concepts associated with the forces of flight. Her belief is supported by her (small) improvement (+2) in performance in the post-test compared to the pre-test (Table 2) and her response in the UPS (Table 3) where she agreed with the statement that using the DLO helped her learn. Although Sinead believed that using the DLO helped her learn, she identified in the UPS she did not find the DLO engaging or fun to use. Sinead also identified that she did not like the forces theme of the DLO.

Sinead mistakenly identified the pre- and post-tests as active components of the DLO. She identified the quizzes and the drag and drop interactivity as the properties of the DLO which engaged her. Responding to a question enquiring about what she liked about the DLO Sinead said;

> *"I could review if I needed to. I really like the pre and post quizzes - all positive… I liked the fact that you could do a pre and post-test ... this provides good incentive to seeing your knowledge grow."*

She also recognised the role that feedback on performance has on motivation, and appreciated that the post-test gave her the opportunity to assess her acquisition of new knowledge**.**

When asked if the interactivity of the DLO helped her learn, Sinead said;

> *"The interaction was good ... the dragging along thing was fun. I like interactive resources; probably good for kids something with repetition and lots of different resources that relate to one another ... these seem to work. You can drag and drop…"*

In her response, Sinead appears to define interactivity as the act of moving the force names around the DLO. She considered that the drag and drop interactivity of the learning object and the repetitive aspects of it made learning fun. In the UPS Sinead agreed with the statement 'the interactivity of the learning object helped me learn' (Table 3). As an Education student, it appeared Sinead was more easily able to make connections with the use of the DLO as a teaching tool. She was able to make the connection to children's learning and engagement.

Sinead identified that she liked the self-directed nature of the learning experience, stating;

> *"I liked to have control over different sections to be able to click at my pace rather than one continuous lesson."*

The forces-of-flight DLO provided users the opportunity to practice associating force names with force direction arrows by click and drag interactivity at their own pace. The DLO provided feedback in response to the correct and incorrect association of force name to force direction arrow. If the user incorrectly matched a force name and force direction the force name returned to its starting position in the DLO and the user was able to try again if they chose to. The DLO was accessed via the Internet so not only could users self-pace their engagement with the DLO they could also access the DLO at a time and from a place of their choosing. The only constraint on accessibility to the DLO was having access to a computer connected to the Internet.

When asked if the multimedia content of the DLO helped her learn Sinead replied;

> *"Graphics were good! What I didn't like ... probably lack of colour? I'm not sure which kind of age group you're aiming for though. Perhaps colour graphics? .... Might make it a bit more appealing, more fun but they were still fine. The visual presentation of the lesson …very simple and clear ... needs colour though."*

Sinead did not comment specifically about the visual modality used to present information, perhaps because she felt she had done this already when responding to other questions. In the UPS Sinead was neutral to the statement ‘the multimedia features of the learning object helped me learn’ (Table 3). In none of her responses to interview questions does Sinead refer to the visual modality of the information presented by the DLO. A reason for this, and her neutral survey response, could be that she could not differentiate between text, images and interactivity as contributing to visual modality or multimedia content. One definition of multimedia is the presentation of visual text and pictures. Sinead’s definition of multimedia may have been different, as she may have expected to be presented or interact with both sound and vision.

Engagement

Hazel

Hazel, when asked whether or not she found the DLO engaging commented:

> *“Yes ... but only a little ... I would like there to be more to it ... like perhaps another element after it where you had to put together a definition of each of the forces or something like that to sort of solidify it a bit more ... something in a different format ... I think with only four items you could guess that [the description and name of the force] and not necessarily engage with it and take much away from it.”*

Hazel’s belief that the DLO was engaging is also indicated in the UPS where she agreed with the statement that the learning object was engaging (Table 3). Hazel considered that the DLO lacked complexity and that presenting material that did not challenge the user could negatively affect engagement. She thought that the provision of additional learning elements, presented in alternative formats, might make engaging with the DLO a more valuable learning experience. Hazel later explains that as a student she has experienced a range of sophisticated DLOs. Therefore, her expectation of a more sophisticated experience from the forces of flight DLO may be due to this. This suggests that there may be a connection between user's prior experiences with DLOs, their expectation and engagement.

Hazel suggested some other changes to the DLO to make it more engaging for the user;

> *" ... some noises or something ... some sort of problem saying such and such ... or you're presented with a scenario and you have to say forces that are involved in that scenario and what forces were involved."*

Hazel recognised the absence of audio content in the DLO and considered that the addition of audio for the presentation of information and questions may enhance user engagement. There is no indication that she felt the added audio content would distract the user's attention from the material presented visually or compete with it.

Hazel also referred to presenting a range of learning activities through the DLO. This could provide the learner with a richer experience and require learners to adopt different problem-solving skills and strategies in response to the presentation of new challenges for the purposes of extending or consolidating learning. The expectation of a more complex experience from the DLO again suggests that Hazel's prior exposure to other learning objects has given her an expectation as to the type of experience she will encounter.

Hazel liked the theme of the DLO, saying;

> *"Yeah ... I thought that was pretty cool ... something I was interested in learning a bit more about."*

Hazel's reply is supported by her response in the USP to the statement 'I liked the overall theme of the learning object' (Table 3). In addition, there is evidence to suggest Hazel was connecting the DLO theme, engagement and achievement.

Sinead

At first, Sinead had difficulty engaging with the DLO and was unsure how to interact with it;

> *"I was a little unsure where to click at first. I did find myself clicking on the plane instead of the dialogue boxes."*

She explained that initially she had not read the instructions but after doing so she found the DLO simple to use. In the UPS Sinead identified that she did not like the theme of the DLO (Table 3). This may have affected her engagement with the DLO to the extent that she was not motivated enough to read the instructions. This is supported by her disagreement with the statement 'Using the DLO made learning fun' (Table 3). Sinead's lack of interest in the forces theme of the DLO may have also influenced her perception of fun in using the DLO. This supports the previous assertion that interest in the subject matter may affect the perception of fun and engagement. Sinead's low pre-test score is possibly indicative of her lack of interest in the subject of forces. The very small improvement in her post-test score compared to her pre-test score further supports this possibility.

Sinead liked the interactive nature of the DLO and that she could use it to learn at her own pace when and where she wished.

> *"Yep ...I liked that it was interactive and self-directed... and that I was able to practice at home"*

As identified in the UPS and as previously discussed, Sinead perceived the DLO's interactivity and anytime anywhere access as beneficial to her learning.

Design

It was intended that the DLO should have user appeal and be easy to interact with. During the design phase, in addition to the pedagogical considerations, attention was given to the placement and balance of elements on the screen, their visual and functional relationship to each other, and making the interface intuitive.

Sinead

When asked what she liked and didn't like about the DLO Sinead replied;

> *"OK graphics. I like the quizzes and drag and drop too. Maybe more colour in the graphics. Other than that [it's] all good."*

Sinead had the following suggestion for improving the presentation of the DLO;

"Perhaps the instructions could have been bolder to encourage me to read ... wasn't that obvious. We all read for what we need"

Sinead's interview response highlights the importance of quite basic elements, such as colour, in DLO design and even suggests that the design of the graphics may be associated with the age of the user.

Hazel

Hazel was asked to identify features of the DLO that she liked and didn't like. Initially she explained those interactive design elements that she felt worked;

"Very simple ... [well] set out ... I like the diagram [referring to the image of the plane] ... it was really clear ... such that it didn't need a whole lot of explanation with it, you knew what it was about from just looking at it."

She continued to comment on some pedagogical aspects of the design that could influence learning;

"I almost felt that it was a little bit too simple. I would have liked to be stretched a little bit more and have to guess. I felt that perhaps the clues were at a lower level than I was at."

During the interview with Hazel it became apparent that she had been thinking about the types of teaching and learning resources she had been exposed to during her study of speech and language pathology. She explained that she was wondering whether any of these resources could be characterised as a DLO;

"In speech and language pathology we have access to a lot of things like schematic models of the human body from various layers from skeleton up to skin and you can rotate them and take off layers and put muscles in order and things like that ... it also has video where people talk about it and they dissect cadavers' ... In stats I don't know if they count as learning objects but we have the online quizzes and videos .... But these were recordings of lectures and I don't know if they qualify as digital learning objects per se."

To better understand Hazel's thinking about learning objects, she was then asked to try to define a DLO;

"Something electronic. Something on the computer ... that you would interact with by using the mouse and keyboard to do something with it ...I guess its computer based and interactive in its most simple definition."

Hazel restricted her definition to learning objects that are computer based and particularly focussed on how DLOs are stored and used. She makes no reference to the DLO having an educational objective.

4.4 Case two: Audio variant

4.4.1 Participants

Five participants, Kate, Robyn, Nina, Chantelle and Melva, were randomly assigned to the audio variant of the DLO. All participants were students studying at the University of Canterbury.

4.4.2 Data collection

The same on-line quiz used in case 1 was used to assess learning performance prior to and after interacting with the DLO. Following some period of time spent interacting with the DLO participants also completed the User Perception Survey (UPS). Kate and Robyn also participated in a semi-structured interview.

4.4.3 Pre- and post-test scores

The pre- and post-test quiz scores for each participant are presented in the following table (Table 4).

Student	**Pre-test score**	**Post-test score**	**Difference**
Kate	12	13	+ 1
Robyn	7.5	12	+ 4.5
Nina	10	11.5	+ 1.5
Chantelle	12	12	0
Melva	12.5	13	+0.5
Average difference between post and pre assessment for group			+1.5

Table 4: Pre and post assessment scores for the audio variant. The difference between pre and post scores are shown

Four of the five participants scored higher in the post-test than they did in the pre-test. This suggests that for these participants using the DLO helped them learn. However, for one participant, Chantelle, the use of the audio variant DLO did not result in any change between her pre and post assessment results. High pre-test scores identified four participants as possessing high prior knowledge of the forces associated with flight. Participants with high pre-test scores also had high post-test scores, indicating that even though they had high prior knowledge they still demonstrated some learning although the differences between post and pre assessment scores were small.

4.4.4 User perception survey

Following interaction with the DLO, each participant completed a DLO user perception survey (UPS). Table 5 presents the results of the user perception survey for the audio variant group.

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Working with the learning object has helped me learn.		1 K		4 R	
The interactivity of the learning object helped me learn.				3 K, R	2
The multimedia properties of the learning object helped me learn.			1 K	4 R	
The instructions in the learning object were easy to follow		1		3 K, R	1
The learning object was easy to use.			1	3 K, R	1
The learning object was well organised.			1	3 K, R	1
I liked the overall theme of the learning object.				5 K, R	
I found the learning object engaging.			1 K	3 R	1
The learning object made learning fun.			2 K, R	1	2
I would use the learning object again.			2 K	2 R	1

Table 5. User perception survey results for the audio variant group. The responses for the participants who were later interviewed, Kate (K) and Robyn (R), are shown.

Results from the UPS identified that participants' perceptions of the DLO were generally positive. Four of the five participants believed that working with the DLO helped them learn. All participants attributed the interactive features of the DLO as having helped them learn (Table 5). Four of the five participants believed that the DLO's multimedia properties helped them learn. This is supported by these participants' results in the pre- and post-tests (Table 4). One participant believed that the DLO's instructions were not easy to follow while four participants perceived the instructions as being easy to follow. Four of the five participants found the DLO to be well organised, easy to use and engaging. Three participants identified that using the DLO made learning fun and indicated that they would use the DLO again. All participants liked the forces of flight theme of the DLO.

4.4.5 Interviews

Learning

Kate

Kate believed that using the audio variant of the DLO did not help her learn. As well as indicating this in the UPS, Kate also added;

> *"I didn't learn from it … … and that is weird because I am familiar with that… but since using the learning object I do have a visual in my head … I do remember."*

Kate scored highly in her pre-test (12 out of 13) indicating that she had a high level of existing knowledge of the forces associated with flight. Given her prior knowledge, the small difference between her pre-post test scores (Δ+1), is unsurprising. Despite indicating that she did not learn from the DLO, Kate did comment that after interacting with it she had a mental pictorial representation (model) of the science concepts associated with the forces of flight.

When asked if the interactivity of the DLO helped her learn, Kate replied;

> *"I liked the way it just didn't fit if it didn't go there, but I got pissed off with it really and [it] ended up just [being] trial and error. After trying to nut it out ... do you know what I'm saying. So I was reading the instructions and going so OK its saying about ...whatever ... ok so I thought if I look at that where can I see a tip or a clue and I just couldn't see."*

Kate liked the feedback provided by the DLO upon the incorrect matching of a force name with a force direction arrow. If this association was incorrect the force name automatically returned to its starting position in the DLO. Kate's response highlights the importance of interactivity and feedback in DLO design.

Kate also identified her frustration at simultaneously needing to attend to the auditory information while undertaking the visual drag and drop matching activity. Kate mentions, *"looking for clues"* however in the audio variant DLO, clues were presented in an auditory modality, not a visual one. Only the aircraft, the movable force names and the force direction arrows were presented visually. Kate's statements suggest that she is unsuccessfully attempting to reconcile two pieces of simultaneously presented information each in a different media modality (audio and visual). This also implies that the instructional message presentation modality and the timing of instructional message presentation are important considerations in DLO design. This may explain Kate's neutral response in the UPS to the statement 'the multimedia features of the learning object helped me learn'.

The audio variant contained four instructional messages, each presented as auditory narrations. Each instructional message was associated with a movable visual force name and described some property or attribute of that force. When a force name was moved around the DLO the associated instructional message was heard. Kate liked the visual presentation of the DLO but believed that the DLO lacked depth of content. When asked if the multimedia features of the DLO helped her learn Kate said;

> *"Although it was pretty there wasn't enough information. There were kind of clues ... in the things that you had to match."*

Kate believed that the DLO did not present her enough new information. Her high prior knowledge may explain her neutral responses to statements concerning learning, multimedia and engagement in the UPS (Table 5). This indicates that content selection in DLO design is important.

Kate did not comment specifically on the modality by which the instructional messages were presented however she did note that the messages contained *"kind of clues"*. The clues that Kate referred to were the descriptions of some attribute of each of the four forces. This suggests that, for Kate, the content of the information was more important than how (the modality) it was presented.

Robyn

Robyn perceived that using the DLO helped her learn (Table 5) and she showed significant improvement between her pre- and post-test score (**Δ** +4.5). She stated that;

"Yes it did [using the DLO helped her learn] ... Hearing the description over the word was very helpful because you can look at the words and say I think I know where those go but then the description cemented that."

Robyn acknowledged that the auditory modality used in the presentation of the instructional messages supported her understanding of the science concepts presented by the DLO. She did not indicate that the simultaneous presentation of the visual force name text, the pictorial representation of the plane and associated forces and the auditory narration were distracting. Rather, she considered this as helping her learn. Robyn observed that information contained in the auditory messages provided clues that helped her correctly associate force names with force directions.

When asked if the interactivity of the DLO helped her learn Robyn said;

"Yes it did ... because it is always fun when you can drag something over where it is meant to go and you can visualize it as well. So for a person that learns visually as well as kinaesthetically it's good. Well I think just being able to do it helped me put it in the right place and see it. It feels a bit like you're doing a puzzle or playing a game so that makes it fun."

Robyn attributed interactivity and the pictorial representation of the forces acting on the aircraft as helping her learn. Robyn did not comment on the auditory modality associated with moving a force name on the diagram. It appears that she did not perceive this as an interactive component of the DLO.

Robyn suggested that the pictorial representation showing the forces acting on a plane was helpful to her learning since the diagram allowed her to construct an internal mental model of the system. Robyn said;

> *"Yes .... the plane was helpful ... having a plane and then showing the directions having the arrows pointing this way and that way and that puts it in your mind.."*

Engagement

Kate

When asked if she found the DLO engaging, Kate commented on how the DLO could be used, rather than describing her experiences of using the DLO. Kate said:

> *"Yes ... it depends on how the course is taught ... for me if the course was being taught online and I had the ability to access this online then I would definitely do it. I think it's helpful in comparison to just reading it in a book ... it would be a helpful addition if I were studying this subject."*

Kate indicated her preference for the interactive, depictive, multimodal presentation of information rather than the text-based presentation of information. In the survey Kate was neutral to the statement 'the DLO was engaging' (Table 5) whilst in the interview she identified her belief that the DLO would be engaging if used in an online course. For Kate, familiarity with the science content of the DLO may have detracted from any sense of fun arising from the use of it, since when asked if using the DLO made learning fun Kate said;

> *"Not really ... I didn't like it because I knew that."*

Kate's consideration of engagement with the DLO from a curricular perspective may result from her experiences as an Education student, or come from her prior experiences of engaging with multimedia learning materials.

Robyn

When asked if she found the DLO engaging and if so why, Robyn said;

> *"I did. As I said I think colour would be more engaging for me personally but it was engaging because it had the spiel [language] about what it was … the force and then you had to drag it and then [get] feedback … so yeah it was quite engaging."*

For Robyn the pictorial representation of the forces acting on the plane, the interactivity and the auditory descriptions of properties of each of the forces made the DLO engaging for her. Robyn believed that the addition of colour would make the DLO more engaging. This illustrates the diversity of design elements such as, media modality, interactivity, feedback and visual aesthetics that need to be considered in the design of DLOs.

In the UPS (Table 5) and in her interview Robyn identified that using the DLO made learning fun. She said;

> *"Yeah it was fun. Like playing a game… Games are always fun, definitely."*

Given Robyn's significantly higher post-test result compared to her pre-test result (+4.5) her statement identifies a possible relationship between fun, engagement and achievement. Games are fun as they meet innate human needs for competition and achievement within a structured framework (rules). Gamification is an emerging instructional technique that employs the mechanics and design of games for the purposes of learning by motivating and engaging learners in game like learning activities.

Design

Kate

Kate believed that the DLO was easy to use and that the accompanying instructions facilitated the use of the DLO. Kate said;

> *"It was easy to follow ... very easy… the instructions were very easy and the wording helpful… I was reading the force names and looking for what was described in the narration and this gave clues."*

Kate identified that the procedural information concerning the use of the DLO was well worded and contributed to the ease of use of the DLO indicating the importance of providing clear and easy to comprehend instructions explaining how to use it. Kate also recognised the auditory presentation of information in the DLO and identified that the auditory provision of prompts and feedback that could support learning are important instructional strategies.

Robyn

Participants will have prior expectations of DLOs, due to their previous experiences of using or interacting with learning objects. Robyn's expectations for DLOs may be related to her previous experiences, since she clearly expected feedback and presentation of further activities after the completion of the matching exercise. Robyn said;

> *"Yes. The only thing was at the end I was wondering if it was going to do something else but then it just finished so I was like oh OK ... I was wondering if there was another one."*

This suggests that user expectation arising from previous use of other DLOs may affect engagement with a DLO. Therefore, experienced DLO users may expect more sophisticated interactive and multimedia features compared to novice users.

4.5 Case three: Audio-visual variant

4.5.1 Participants

Four participants, Bex, Bri, Vicky and Carmen, were randomly assigned to the audio-visual variant of the DLO. All were students studying at the University of Canterbury.

4.5.2 Data collection

As described in the previous cases, an on-line quiz was used to assess learning performance prior to (pre-test) and after (post-test) interacting with the audio-visual DLO. The on-line quiz consisted of 13 questions designed to assess participant knowledge of science concepts regarding forces associated with flight. Following a period of time spent interacting with the DLO students also completed a User Perception Survey (USP). Vicky and Carmen also participated in a semi-structured interview.

4.5.3 Pre and post-test scores

The pre and post-test on-line quiz scores for each of the participants are presented in the Table 6.

Student	Pre-test score	Post-test score	Difference
Bex	7	12	+ 5
Bri	9.5	12	+ 2.5
Vicky	13	13	+ 0
Carmen	5.5	9	+ 3.5
Average difference between post and pre assessment for group			+2.75

Table 6. Pre and post assessment scores for the audio-visual variant group. Differences between pre and post scores are shown.

Pre and post-test results show that three of the four participants had higher post-test scores than pre-test scores. This suggests that these participants gained new knowledge regarding the science concepts associated with the forces of flight. One participant's post-test score was identical to her pre-test score, with Vicky scoring full marks in both the pre and post-test. This identified Vicky as possessing high prior knowledge about the science concepts associated with forces of flight. Participants with the lowest pre-test scores (Carmen and Bex) demonstrated the largest increases between pre and post-test scores.

4.5.4 User perception survey

Following interaction with the DLO, each student completed the user perception survey. Table 7 presents the results of the User Perception Survey (UPS) for the audio-visual variant group.

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Working with the learning object has helped me learn.			1	3 C, V	
The interactivity of the learning object helped me learn.			1	2 V	1 C
The multimedia properties of the learning object helped me learn.				4 C, V	
The instructions in the learning object were easy to follow			1	1 V	2 C
The learning object was easy to use.			1	1 V	2 C
The learning object was well organised.			1	2 C, V	1
I liked the overall theme of the learning object.				4 C, V	
I found the learning object engaging.			1	3 C, V	
The learning object made learning fun.			1	3 C, V	
I would use the learning object again.			1	3 C	

Table 7. User perception survey results for the audio-visual variant group. The responses for participants who were interviewed, Carmen (C) and Vicky (V) are shown.

Participants generally had positive impressions of the audio-visual variant DLO (Table

7). Three of the four participants believed that using the DLO helped them learn and attributed the DLO's interactivity and multimedia features as the reasons why it helped them learn. Three participants believed the DLO to be engaging identifying the forces of flight theme, the DLO's ease of use and the fun they experienced using the DLO as the reasons for this. This indicates a relationship between the extent of prior knowledge, design, engagement and learning.

4.5.5 Interviews

Learning

Carmen

Carmen believed that using the DLO helped her learn. She stated;

> *"I like the visual ... being able to look at the explanations or definitions on the screen but also being able to hear them was really cool. So I definitely learnt something although I did know a lot of that ... there were a couple of little bits that I did pick up so that was good."*

Carmen attributed her learning to the pictorial representation of the aircraft and associated forces and the simultaneous audio-visual presentation of the information associated with the force names. Positive differences between Carmen's pre and post-test scores (+3.5) and her responses in the UPS (Table 7) support her belief that using the DLO helped her learn.

When asked why she thought that using the DLO helped her learn Carmen said;

> *"... I like using technology to learn things anyway ... it's nice and clear and easy to use and nice and simple."*

Carmen's liking of the use of technology for learning provided her with motivation to engage with the DLO. Carmen considered that the clarity and simplicity of the DLO's organisation and its usability made it easier for her to learn from the DLO. Clarity and simplicity of design can reduce the extraneous cognitive load experienced by users.

The forces of flight DLO enabled users, via click and drag interaction, to construct a complete pictorial representation of the forces associated with flight. Carmen perceived that this interaction helped her learn and for her this was a better way to learn. When reflecting on the interactivity of the DLO, Carmen said;

> *"I definitely learn better if I am actually doing something, so actually being able to do it and move things around while listening to it ... was really good ... being able to do something other than just listening is good. I think for me."*

Exploring this theme further Carmen was asked why she thought that the DLO's interactivity helped her learn.. Carmen replied;

> *"I think it is just the type of learner that I am. Rather than just reading something I prefer to be doing something and I think it helps me learn better. So that I find if I'm shifting things around and having to think about that then that seems to work better for me."*

Carmen, when considering the multimedia features of the DLO, suggested that the simultaneous presentation of information in audio and visual modes helped her learn. Carmen liked reading the text while simultaneously hearing a narration of the text.

> *"I definitely liked listening as well as being able to read it ... I probably would have thought that normally I am a listening person ... so I read along to someone's voice and I found that really, really good."*

Carmen also commented that the multimedia presentation of the DLO could have been improved by increasing the font size of the visually presented text, indicating the importance of even simple presentation design elements that may influence engagement.

Vicky

Vicky identified that she had a high prior knowledge of the forces associated with flight from her previous work. She scored full marks in both the pre- and post-tests and did not feel that the DLO helped her learn.

> *"No… because I know about the forces of [flight]… I have a lot of prior knowledge ... I was in the navy for fifteen years and know of forces and stuff ...."*

However, Vicky did indicate that *"If I didn't know about forces in flight I suspect it [DLO] would have done [helped me learn]".* She went on to explain why she thought the interactivity of the DLO would help someone learn, particularly identifying the game-like quality that made it engaging.

> *"I think it definitely would because if you try something and it doesn't work it sends you back so you have to keep on trying out to see where it goes to ... so if you put thrust [force] in the wrong place it bounces back so its immediate that you have not got it right so you keep on trying...*

basically it turns into a game .. where can I get it to go and make it stick. And then of course the voice over tells about what that force does. So I think the interactivity does help because it's not just sitting there reading something. You're actually moving something around and doing something. So I think that helps learners."

Engagement

Carmen

When asked if she found the learning object engaging Carmen said;

> *"I did ... it was engaging enough, although I knew quite a bit of the information and it wasn't new to me… it was engaging for me in terms of technology .. I like it… it was nice and easy to use and I was able to get information quite quickly and work out where everything was going to go. I think if the information was all new it would be really engaging for me."*

Although Carmen found the DLO engaging, she indicated she knew *"quite a bit of the information"*, however her pre-test score indicated fairly low prior knowledge (Table 7) and her post-test score increased indicating that use of the DLO helped her learn. As such, Carmen's UPS, interview and pre-post assessment results suggest relationships between usability, interactivity, engagement and learning.

Previously, Carmen had identified that as a learner she enjoyed using technology. She also acknowledged that as a learner she preferred a face-to-face setting to allow her to interact with the teacher. Carmen suggests that the use of the DLO, for her, was best suited to independent self-directed activities for the consolidation and reinforcement of learning.

> *"I like learning ... when I'm doing independent tasks I would much rather do them on the computer than reading although I still prefer going into a lecture or learning environment and doing face to face because you get the option to ask lots of questions. Obviously in this case if you didn't know what you were doing or if you were stuck or you wanted to know more information then you haven't got that opportunity to talk to someone about that straight away."*

Carmen also liked the theme of the DLO, saying;

> *"... I found it quite interesting ... yeah it was really interesting. I quite like flight so, yeah, it was good."*

Vicky

Vicky, when asked whether or not she found the DLO engaging commented;

> *"Yeah. It was because you're looking at it trying to decide what the answer is. It makes you think about what and why and then go and try it out and see if it works or not. If you try and put it in the wrong place it goes back and you start thinking why hasn't it gone in that place .. I thought that that should go there but of course with thrust and drag people can get them in the wrong place. They can think they are opposite because of the arrows ... the way the forces work .... people can get confused as to which way the forces actually work ... they might think that thrust goes at*

the back of the aero plane because it thrusts it forward when in actually thrust goes at the front as that's the way the force is moving."

Vicky's response is supported by her agreement with the engagement statement in the UPS (Table 7). Vicky attributed the DLO's physical interactivity and the challenge of completing the pictorial representation of the forces associated with flight as engaging. She also acknowledged the role of feedback provided to users by the DLO while attempting to assemble the pictorial representation. Pictorial representations can be an effective way in which to present information complex to convey as written text. Vicky suggested that the pictorial representation of the forces acting on an aircraft could help clarify misconceptions concerning the direction of operation of the drag and thrust forces.

Vicky also believed that the DLO made learning fun. When asked if the DLO made learning fun, Vicky instead commented on how school students might perceive DLO's as fun. She attributed this to the previous experiences of children may have had with digital technologies

"I think it was definitely fun to use but also if I look at kids in a school they get the iPads out and they just want to play on the iPads all the time ... they are just so engaged with the idea of moving things around screens and they love doing that, so yeah it was fun to use ... if I was looking at the year three children, for example, and if they wanted to know about forces they'd really enjoy it. I think they'd find a lot of fun doing that because it's just part of the way kids are being brought up now to use digital objects and to try out things and play with them to find out how it works."

When asked if she liked the DLO's theme Vicky said;

> *"Yeah .. it's an interesting one because if you're learning about forces it is such a massive thing it can be very abstract but when you start applying it to an object such as a aeroplane or a car or something similar like that .. yeah ... it gives it a bit of a theme and it means that kids can look at an aeroplane in the sky and relate what they are learning to what they're actually seeing in the sky. They can watch an aeroplane and say "I can see the forces are doing this and this and this" ... they can put it in context."*

Vicky believed that the pictorial representation of the forces acting on an aircraft contextualised learning. The pictorial representation of abstract science concepts that are difficult to explain in words can be a useful strategy that can facilitate learning.

Design

Carmen

Initially, Carmen experienced difficulty using the DLO. She attributed her difficulty to not reading the instructions in the first instance. Once she had read the instructions Carmen found the DLO easy to use and she quickly engaged with it. She stated;

> *"I found it nice and easy ... and having read the instructions I knew that if I got it right that it was actually going to stay there [the label] so I knew straight away if I had it right or wrong."*

Carmen also commented on the timing of the feedback delivered by the DLO. She perceived instantaneous feedback as better than delayed feedback.

In terms of the design and organisation, Carmen noted;

> *"The instructions are at the top which is very handy. The definitions on the left is good for me although left or right would have been fine. The boxes are nice and big so that the words actually fit into them which is really good and the arrows around the aero plane made it really obvious where I was meant to be putting things."*

She believed that the logical layout of the DLO and the effective use of visual space to accommodate the DLO's click and drag interactivity contributed to the learning objects usability. This identifies the importance of visual design and the presentation of procedural information to DLO design.

Vicky

Vicky, when asked if she found the instructions easy to follow, replied;

> *"Yeah .. it just said what to do so you just do what it said ... It was simple. It was definitely easy to use … as long as you have got a mouse … and you know how to use the mouse and click and drag things."*

Vicky's comment regarding the importance of prior experiences with digital technologies supporting DLO use assumes that users carry with them transferable skills learnt through their previous interactions with digital technologies.

Vicky also identified that the DLO was well organised, saying;

> *" it worked well ... the list of the forces is on the left hand side and you just drag them across and having that aero plane there… It was quite logical to move things from the left to the right because that's how people write anyway, so that idea of moving from one side to the other to drag and drop ... yeah I find it pretty easy to use. It seems logical to me in that way to drag and drop."*

She perceived the DLO's left to right design mirrored a familiar logic that contributed to making the object easy to use and well organised. Vicky's observations also suggest it is important to ensure presentation and interaction designs are attuned to the cultural expectations of the target audience, which in this case related to the writing system.

Chapter 5 Discussion

In this chapter the results from the pre and post-assessments, user perception survey and interviews are discussed in relation to the research questions and the reviewed literature. The research questions were:

1. How did the modality of instructional messages presented by the forces of flight digital learning object affect learning and perceptions of learning?
2. What properties of the forces of flight digital learning object did users perceive as supporting learning?

The presentation of the discussion is by theme. The themes, derived from Kay's (2011, 2012) Web Based Evaluation Scale (WBLT), are learning, engagement and design.

5.1 Learning

This research investigated the impact of different media modalities on learning and sought to identify the design elements of a digital learning object perceived as being supportive of learning.

What is learning?

Learning is a fundamental human behaviour and is described by a number of different theories. Behaviourist, cognitivist, humanist, social learning, and constructivist theories of learning all offer a unique perspective of learning. A theme common to all of these theories is that learning involves the acquisition, recall and application of new information (Merriam, Caffarella & Baumgartner, 2007). In this research, learning was defined as the acquisition and recall of information about the forces associated with flight. Learning was measured by improvements in participants' scores in pre and post assessments. Measuring learning by comparing differences in pre and post-assessments is a common approach in psychological and multimedia learning research (for example Ardac & Akaygun, 2004; Butcher, 2006; Chen & Sun, 2012; Crooks, Cheon, Inan, Ari & Flores, 2012; Mayer, 1989; Mayer & Anderson, 1992; Pedra, Mayer & Albertin, 2015; Tindall-Ford, Chandler & Sweller, 1997).

5.2 Modality and learning

In this study, each DLO variant presented participants with identical information describing two unique properties of each of the four forces associated with flight. Each variant presented this information through a different media modality. The media modalities used were: written words and an illustration (case 1 - visual), spoken words and an illustration (case 2 - auditory) and spoken and written words and an illustration (case 3 – audio-visual). Participants could score a maximum of thirteen marks in the pre and post-assessments for questions requiring the recall of this information. The average improvement in post-assessment scores compared to pre-assessment scores for each media modality (case) was:

- +3.12 (case 1-visual, n=4)
- +1.62 (case 2-audio, n=5)
- +2.75 (case 3-audio visual, n=4)

An increase of +3.12 marks equates to a 24% improvement in learning performance, an increase of +2.75 represents a 21% improvement and an increase of +1.62 is a 12.5% improvement in learning performance. Within the limitations of this research, the results could be interpreted as showing that use of any variant of the DLO supported learning and that the visual and audio-visual modalities best supported learning, while the audio modality least supported learning. Various researchers (e.g. Mayer 2001, 2005, 2009, 2014; Moreno, 2006; Moreno and Mayer 2007 and Tindal-

Ford et al. 1997) have reported that people are more able to acquire and recall information that is presented as pictures and spoken words rather than pictures and written words. This is called the modality principle. Cognitive Load Theory (Sweller, 1998, 2005), Dual Coding Theory (Paivio, 1986) and the Cognitive Theory of Multimedia Learning (Mayer, 2005, 2014) describe a mechanism for the modality principle. These theories propose that presenting information as spoken words and pictures lessens the extraneous cognitive load experienced by learners because the cognitive load is spread across two processing channels (the auditory and visual channels). As both channels are limited in their processing capacity, spreading the work across two channels effectively expands the capacity of the working (short-term) memory. Presenting information in a single modality, for example as written text and pictures, may exceed the limited capacity of a channel resulting in a large extraneous cognitive load being placed on the learner (Mayer, 2001, 2009; Moreno, 2006). The following image (Figure 10) depicts the proposed mechanism of modality effects. The grey boxes in the illustration represent areas where cognitive load is experienced.

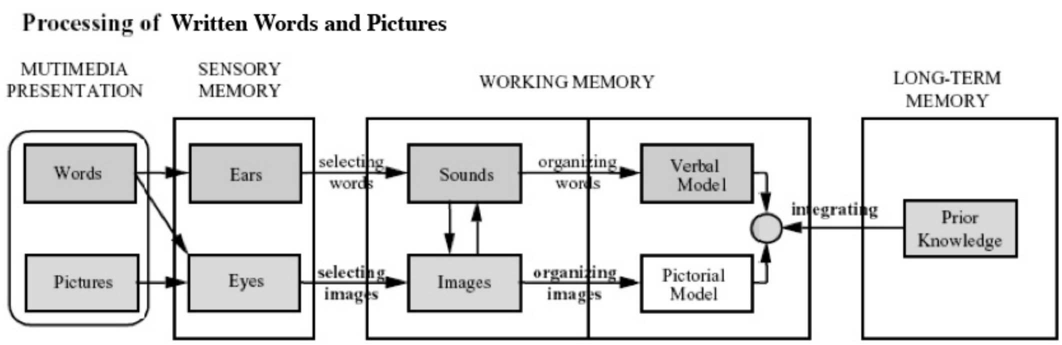

Figure 10. Cognitive load with spoken and written words (Mayer, 2005, p.37*)*

As described in the literature review (Chapter 2) there is debate as to where the cognitive overload occurs; in the sensory memory or in the working memory or in both (Crooks et al., 2012; Rummer, Schweppe, Furstenberg, Schieter & Zindler, 2011; Rummer, Schweppe, Furstenberg, Seufert, & Brunken, 2010). According to the modality principle, use of the audio-visual variant (case 3) should have best supported learning whilst use of the visual variant (case 1) should have least supported learning. As such, the results from this study appear to contradict the modality principle as the visual variant show the largest average increase in post-assessment score over pre-assessment score. One possible explanation for the results could be the extent of participants existing knowledge about the forces of flight. The high pre-assessment scores of some participants in each of the three cases identified the presence of high prior knowledge participants. That is, people who already knew the presented information. As identified by the prior knowledge principle, the extent of a learners existing knowledge about a concept will influence their learning from a multimedia DLO that provides instruction about that concept. In this research, the presence of high prior knowledge participants may have influenced modality effects. Findings from Moreno (2006), Ginns (2005), Kalyuga and Chandler and Sweller (2000) show that the modality effect is most likely to occur for low prior knowledge learners if the content to be learned is complex and if the DLO, rather than the learner controls the pace of instruction. Furthermore, modality effects may reverse for high prior knowledge learners. Pre-assessment results for case 3 (audio) indicated that three of the five participants possessed high prior knowledge. As such, the pre-post assessment results for case 3 (audio) suggest a reverse modality effect due to the presence of high prior knowledge participants. The results show that low prior knowledge participants displayed the largest improvements in pre-post assessment scores regardless of the modality. As such, in this study, the extent of prior knowledge appears to be a better predictor of improvements in learning performance as measured by pre and post-assessments than the media modality of the instructional messages. While the results suggest a possible relationship between prior knowledge, media modality and learning, the small differences between pre-post scores, within and between cases, and the low number of research participants make drawing conclusions tenuous at best. However, the proposition that relationships exist between the learner's prior knowledge, the media modality of the presented information and learning is evidenced in the literature and suggested by the results. What can be tentatively concluded from the results is that use of any variant of the forces of flight DLO resulted in learning improvements, as measured by increases between pre and post-assessment scores.

Modality and DLO design

The design of DLOs and DLO modality can be informed by the application of the modality principle. Moreno's (2006) 'media enables method' hypothesis proposes that DLO design possibilities may be exploited for instructional purposes. For example, a DLO could be designed to address the modality principle and modality reversal effects due to the presence of high prior knowledge learners and self-pacing. Such a DLO could incorporate testing and scoring in its design. As users engage with the DLO a score is generated based upon their performance. As a learners performance improves the modality of the presented information changes. For example, from spoken text to written text. This type of dynamic design, common in contemporary digital games, could be applied to the design of a DLO as a way of exploiting both modality and modality reversal effects in order to support learning. The design possibilities afforded by contemporary technologies used in the creation of DLOs allows for a diversity and complexity of functionality that has not been researched to great depth. Further research in this area is required (Inan, Crooks, Cheon, Ari, Flores, Kurucay and Paniukov, 2015).

5.3 User perceptions

The interview and UPS data shows that participants from all three cases found the presentation of information in verbal (text) and non-verbal (images) modes helpful to their learning. Participants from all three cases revealed their beliefs that the presentation of information in verbal and non-verbal modalities enhanced their understanding of the forces acting on an airplane in flight; revealing a "liking" for the pictorial representation and a perception that the presentation of information in this format helped them learn. Some participants expressed the view that the pictorial representation helped clarify misconceptions, situated learning in an authentic context and perceived it as a useful means to portray the concept of forces and flight.

The use of non-verbal visualisations (pictures and illustrations) in learning and teaching is ubiquitous. Much research has been conducted into the value of pictures for depicting phenomena that is difficult to represent in words alone, by presenting complex information in a form that is easy to understand (Mayer, 2001, 2005, 2009, 2014). Although the Multimedia Principle (Mayer, 2001) has shown that low prior knowledge learners benefit from the presentation of information in both verbal and non-verbal modes, some researchers have expressed reservations about the generalisability of the multimedia principle (Acha, 2009; Kim, Kim & Whang, 2013 and Schnotz & Kürschner, 2007). In their studies, Kim et al. (2013) and Schotz & Bannert (2003) demonstrated that the addition of non-verbal information (pictures) to verbal information (text) did not always lead to improved learning performance, concluding that verbal and non-verbal information played fundamentally different roles in mental model construction. They proposed that initial mental model construction was being verbally driven with non-verbal information acting as a scaffold supporting its construction. Kim et al. (2013) conducted three experiments involving 15 and 16 year old learners using English and Mathematics DLO's whose designs were based on the principles of the CTML. They reported contradictory findings with respect to learning and the presentation of information in verbal and non-verbal modalities. They concluded that learners have specific cognitive learning dispositions, either as verbalisers or visualisers, and proposed that these cognitive dispositions influenced the modality effects. Furthermore, they concluded that learner emotions also influenced learning and moderated the modality effects. In this research, some participants from all three cases reported a self-perception of their own learning style. Some participants perceived themselves to have an auditory learning style while others believed that they had visual or kinaesthetic learning styles. This is in keeping with Cognitive-affective Theory of Learning from Media (CATLM) (Moreno, 2006), in which it is proposed that learners' affective characteristics (such as emotions, motivation, expectations and beliefs) influenced cognitive learning processes and therefore learning. In this study, the results from the UPS and interviews appear to support the proposition, evident in the literature, that affective characteristics of learners' influences learning and perceptions of learning. As such, a DLO design could provide learners the ability to self-select modality. It could be argued that such a design could promote learning, as the experiences provided are aligned with the users learning style. However, consideration of all of the results (pre-post assessment, interviews and UPS) identified discrepancies between the objective measures of learning, as identified in the pre-post assessment, and the subjective measures of learning, as identified by participants in the UPS and interviews. This suggests that a learner's self-perception of their learning style may not be accurate. The implication of this for DLO design is that there may be a danger in providing learners control over DLO modality that may arise from a learners belief that they possess a specific learning style. However, this could actually be a media preference rather than a learning style. A consequence of this could be that a learner consciously selects a modality they liked, yet that modality could be cognitively detrimental to their learning. This presents a challenge to DLO designers seeking to strike a balance between DLO functionality, the cognitive and affective characteristics of learners and learning. The application of the principles of CTML and CATLM could be of assistance in this regard. At the very least, knowledge of these principles makes overt to DLO designers the potential influence of DLO functionality on the cognitive and affective processes of learners. At the other end of the spectrum the implementation of the principles of CTML and CATLM could result in the creation of DLOs that, being aligned with the innate cognitive and affective processes of learners, facilitate learning.

5.4 Engagement

Engagement concerns the extent of a learner's attention, curiosity, interest and passion when learning about a particular topic (Kay, 2007). Subject matter, learning context and personal characteristics and preferences of individual learners all contribute to the extent with which people engage with learning, therefore engagement influences learning (Moreno, 2006).

In this study, participants from all three cases identified the following two interactive DLO features as helpful to their learning and promoting engagement: These features were common to all variants.

1. **Click and drag interaction**: All variants of the forces of flight DLO presented users with an incomplete pictorial representation of the forces acting on an airplane in flight. Using click and drag interactivity, participants had to complete the pictorial representation by dragging force names to an arrow indicating the direction of operation of that force.
2. **Self-pacing:** Participants could spend as little or as much time as they wished interacting with the DLO.

5.4.1 Click and drag interactivity

UPS results showed that all participants from case 1 (visual) and case 2 (audio) believed that the DLOs interactivity helped them learn. Interviewed participants from all three cases believed that the physical act of arranging and re-arranging the movable force names in order to complete the pictorial representation helped them learn. The interview results also indicated that participants believed that the learning benefits of interactivity were due to more than just the physical act of selecting and moving the force names. During the interviews, some participants described thinking about the correct association of force name with the force direction arrow as they were moving a force name around the DLO. For example, one participant described how she made a conscious decision to engage with the DLO rather than simply trying random combinations to achieve a correct result. Other participants described how they attended to the instructional messages that were presented when they selected a force name and how these messages contained clues that assisted them in responding correctly. This attests to the perceptual sensing and cognitive selection and organising as participants interacted with the learning object.

Behavioural interaction may initially motivate some learners to engage with a DLO, however for learning to occur learners need to cognitively interact with the digital learning object and it's content (Mayer, 2005, 2014). Cognitive interaction with the forces of flight DLO required participants to select, organize and re-organize force names in order to complete the pictorial representation of the forces affecting an airplane in flight. In the forces of flight DLO behavioural engagement resulted from users having to organize the selected force names by physically associating these with arrows indicating the direction of operation of each force. As previously described, if the association of force name and force direction arrow was correct the force name "stuck" to the arrow. If the association was incorrect the force name automatically returned to its starting position in the DLO. This interaction/feedback process provided participants the opportunity to complete the pictorial representation through a process of behavioural and cognitive interaction. Furthermore, some participants likened their interaction with the DLO as resembling solving a puzzle or playing a game. Such responses suggest that participant's behavioural interaction promoted cognitive interaction with the DLO, which in turn supported learning. "Gamification" is an emerging instructional technique that employs the mechanics and design of games for the purposes of learning by motivating and engaging learners in game and puzzle-like learning activities (Bouvier, Lavoue, Sehaba, & George, 2013; Clark, Tanner-Smith, Killingsworth & Bellamy, 2013). However this prompts questions concerning the nature of user interactions with a game. As discussed above, two kinds of activity related to learning exist, behavioural activity and cognitive activity (Mayer, 2005,

2014) therefore learners' engagement with games could be considered as being behavioural and/or cognitive. DLO presentation designs that involve the presentation of a DLO as a game or puzzle should adopt designs that promote cognitive interaction via the use of behavioural interactions that prompt cognitive activity (Lui & Chu, 2010). Although the gamification of DLOs may initially motivate the learner to engage with the learning object, designs that impart too high a cognitive load on learners may erode any motivation to continue interaction and consequently be detrimental to learning (Ke and Abras, 2013). Despite extensive research on games this has largely been in an entertainment context and there exist few empirical studies that explore game based-learning (Jabbar and Felicia, 2015).

In summary the results indicate that the behavioural and cognitive interactive properties of a DLO can support learning and as such these are important properties requiring attention in the development of DLOs.

5.4.2 Self pacing

In the interview results, a number of participants commented positively on the self-directed nature of the DLO interaction. By allowing participants to proceed through the DLO content at their own pace, they could pause and reflect on new information in order to associate it with existing mental representations or construct new mental representations before responding. This interpretation is identified in the cognitive instructional design literature as the Segmenting Principle of the Cognitive Theory of Multimedia Learning (Mayer, 2005, 2014; van Merrienboer & Kester, 2005). The Segmenting Principle posits that people learn better when instructional messages and activities are presented in learner paced "chunks" or segments rather than as one continuous episode. The Segmenting Principle also proposes that giving learners control over the pace of instruction can enable them to slow the pace of instruction when they experience high cognitive load, usually, when they encounter material that is difficult to understand due to its complexity.

Interview results from the high prior knowledge participant Kate (case 3) revealed her frustration with having to attend to different pieces of information presented simultaneously in both auditory and visual modalities. This frustration may have arisen because of the transient nature of the auditory information presented to her and her lack of control over the playback of the audio recordings. A possible relationship between media modality and self-pacing has been identified in the literature (Mayer, 2001, 2009; van Merrienboer & Kester, 2005) and suggests that the presentation of information in transient media modalities (video, audio, animations) can impose a large extraneous cognitive load if the pace of presentation of information in transient modalities is not under the learner's control. However there is contention in the literature as to the learning benefits arising from providing learners increased control over the pace and sequence of instruction. A meta-analysis of the learner control within educational technology literature research conducted by Karich, Burns and Maki (2014) concluded that the effect of learner control within educational technology was almost zero and as such learner control over the pace and sequence of instruction did not influence academic outcomes to a significant extent.

5.5 Learner perceptions

Comparisons of the interview, UPS and pre-post assessment results from all three cases suggest a possible relationship between participants' perceptions of learning and

DLO design features. For example, some participants perceived that DLO interactivity supported their learning. Other participants identified the information presentation modality as helping them learn. The cognitive affective theory of learning with media (CATLM) (Moreno, 2006), and research by Mayer (2014) and Kim et al. (2013) suggests that learners' emotions can affect engagement with a digital learning object. Research conducted by Plass, et al. (2013) demonstrated that the addition of appealing colours and positive emotional graphic design elements to instructional illustration's improved learner performance in comprehension tests and learner self-ratings of motivation when the "beautified" graphics were essential to learning. This is the emotional design hypothesis. The emotional design hypothesis proposes that increasing the visual aesthetic of graphics that are essential for learning has a positive affect both on learning and engagement. Plass et al. (2013) demonstrated that this affect was particularly pronounced for low prior knowledge learners. Magner, Sckwonke, Aleven, Popescu and Renlkt (2013) explored this effect further in comprehension tests and discovered that the addition of appealing graphics, not essential for learning, negatively affected learner performance but still resulted in high motivation scores. This was termed the interest hypothesis. The emotional design hypothesis and the interest hypothesis demonstrate the limitations of adding attractive multimedia features to instructional messages. Therefore, it is unsurprising that in this study some participants believed that the addition of specific affective design elements might have made the DLO more appealing. However, DLO designers need to be aware of the potential positive and negative affects of using attractive multimedia features solely intended to promote engagement, since they may encourage engagement but they may also impose an extraneous cognitive load on the user and consequently negatively impact learning. In other words, simple multimedia designs may better support learners than attractive, affective designs. The interview results from this study appear to suggest this. A number of participants from all three cases made positive references to the clear and simple illustration used in the forces of flight DLO. With UPS and interview results from all three cases also identifying that participants believed that the usability and general organisation and layout of the DLO positively affected engagement and learning. The results from all three cases suggest that DLO design features, such as the use of affective media, usability and layout and organisation, may affect learner motivation, engagement and beliefs with regard. Evidence from this study, although limited, suggests that learner emotions including expectations, belief, interest and motivation may influence learning. However, research in this domain is in its infancy. Brunken, Plass, and Moreno (2010, p. 262) note,

> Although it is well known that metacognitive, affective, and motivational constructs are central to learning, they have not been the focus of cognitive load research … Therefore, there is great potential to test specific hypotheses about the relation among motivation, cognition, cognitive load, and learning (Brunken, Plass, and Moreno (2010, p. 262).

In this research, the results appear to suggest a poor correlation between learning as measured by the objective pre-post assessments and perceptions of learning as measured by the subjective UPS and interviews. However, care must be taken when analysing data that use subjective and objective measures. In their analysis of 10 years' worth of data, Bangor, Kortum and Miller (2008) concluded that subjective measures of users perceptions are often poorly correlated with objective measures. In contrast, Davids, Chikte, Grimmer-Somers & Halperin, (2014) investigating usability of DLOs used in health education did observe some correlation between objective and subjective measures of learning.

5.6 Usability

In this study, the results showed no evidence that the DLOs usability influenced participants' perceptions of learning. As described in the UPS and interview results, participants from all three cases found the forces of flight DLO well organised and easy to use. Usability of a DLO has been identified as a major influence on learning and users self-reported feelings of satisfaction (Davids et al., 2014; Sandars & Lafferty, 2010 and Sim, MacFarlane & Read, 2006). However, Sim et al. (2006), in a study of primary aged school children, concluded that the complexity of the subject matter, how the DLO was used, the characteristics of the learner and DLOs design and usability collectively contributed to determine a DLOs educational effectiveness than usability alone. Although usability alone is not sufficient to achieving educational outcomes (Sandars & Lafferty, 2010; Sim et al., 2006), usability is important to DLO design since learners are less likely to engage with DLOs that are difficult to use. Davids et al. (2014) and Sandars & Lafferty (2010) note that while usability testing is common in software development life cycles it is often neglected in the development of digital learning objects. These authors call for DLO usability testing to be conducted iteratively throughout the design process in order to prevent the creation of DLOs whose usability renders them detrimental to learning. The design phase used in this research is an example of this type of usability testing.

In this study, the results from all three cases appear to support the notion that the combination of DLO design, topic of instruction (context) and the beliefs, experiences and expectations of individual participants together may influence learning and perceptions of learning. Usability does not appear to have influenced participants' perceptions of learning.

5.7 A visual model of DLO design

The results of this research suggest, and the reviewed literature identified, a number of elements that require consideration when designing a DLO. The application of the Technological Pedagogical Content Knowledge (TPCK) framework (Mishra & Koehler, 2006) to DLO design provides a useful visualisation of these elements and the interactions between them. The framework (Figure 11) identifies the knowledge domains required by teachers in order to teach effectively with technology. TPCK builds upon Shulman's (1986) pedagogical content knowledge model (PCK) and proposes that the effective use of technology in learning and teaching requires understanding of three knowledge domains: pedagogy, content and technology and the relationships and interactions between these knowledge domains. The application of TPCK framework to DLO design provides an easy to comprehend visual model that identifies essential considerations that are applicable to DLO designs that will support, rather than detract, from learning. The application of TPCKs knowledge domains can be connected to DLO design in the following way:

- Context
  - knowledge of the learners characteristics such as extent of prior knowledge, gender, age, previous experiences, expectations and motivations.
- Pedagogical knowledge (PK)

    - knowledge of appropriate instructional design approaches implemented in the DLO aligned with specific learning outcomes.
    - knowledge of cognitive instructional design theories such as Cognitive Load Theory and Cognitive Theory of Multimedia Learning.
    - knowledge of affective theories of learning. For example, Cognitive Affective Theory of Learning from Media (CATLM).
    - knowledge about the characteristics of the learners.
- Technological knowledge (TK)
    - knowledge of the technology used for the creation of DLOs.
    - knowledge of the functionality and affordances of the published media. For example, file formats, accessibility, re- usability, and the use of metadata for discovery.
    - knowledge of learner's characteristics.
- Content knowledge (CK)
    - knowledge about the topic of instruction and learners characteristics.
- Pedagogical Content knowledge (PCK)
    - knowledge of effective instructional design approaches for the topic of instruction and the intended learners
- Technological Content knowledge (TCK)
    - knowledge about the technical functionality of the computer applications being used to create a DLO and how this functionality can be used in the presentation of content to learners.
- Technological pedagogical knowledge (TPK)
    - knowledge about ways in which technology can support the DLOs instructional design. For example, cognitive and behavioural

interactivity, feedback (stimulus- consequence- response), Learner control over sequence of instruction

- knowledge of the characteristics of the learners.

• Technological Pedagogical Content Knowledge (TPCK)

  - knowledge and understanding of the interactions between the TK, CK, PK and contexts
  - knowledge domain and the relationships between learner characteristics (expectations, prior knowledge, beliefs, metacognition, etc.) content, instructional design and technology.

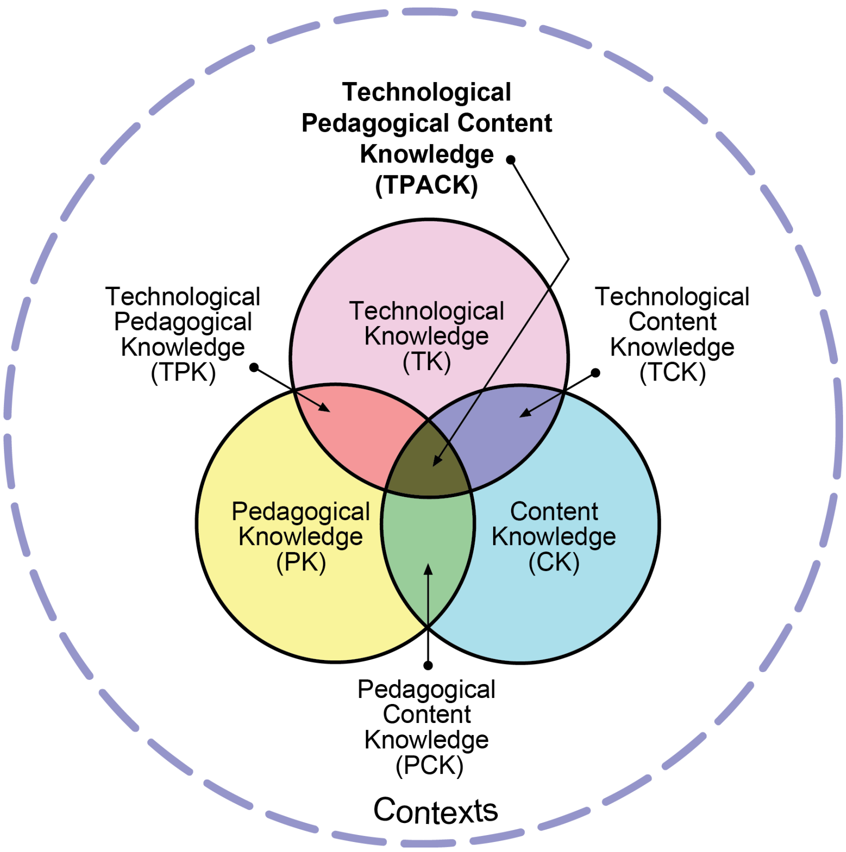

Figure 11. The TPCK model (Mishra & Koehler, 2006)

The application of the TPCK framework to the DLO design process could support DLO creators as they attempt to visualise the interacting evidenced-based, principles of multimedia design.. The conceptualisation of DLO design using the TPACK framework is an example of the use of the multimedia principle. This is, the explanation of the concept of DLO design using a combination of words and pictures to identify the evidenced multimedia design principles identified by CATLM and CTML research that when implemented result in designs that enable learning by guiding, enhancing and amplifying the cognitive processes of learners.

Chapter 6 Conclusion

This research sought to contribute to the DLO research base by answering the research questions:

1. How did the modality of instructional messages presented by the forces of flight digital learning object affect learning and perceptions of learning?
2. What properties of the forces of flight digital learning object did users perceive as supporting learning?

Taken as the whole, the results suggest that the modality of instructional messages presented by the forces of flight DLO variants supported learning and perceptions of learning by affecting the cognitive and affective processes of learners. This assertion is supported in the literature. Specifically, by the Cognitive-Affective Theory of Learning from Media (CATLM) (Moreno, 2006) and the Cognitive Theory of Multimedia Learning (CTML) (Mayer, 2005). Furthermore, the results suggest, and the reviewed literature identified, that learner cognitive and affective characteristics together act to influence modality effects. An example of this is the influence of learners' prior knowledge on modality effects.

Modality and interactivity were two DLO properties that participants from all cases perceived as helping their learning. Modality and interactivity are identified in the CTML and CATLM literature as DLO properties that affect learning and perceptions of learning. As such, I propose that CATLM and CTML be used as frameworks that inform evidenced based DLO design guidelines. The application of such guidelines could contribute to the creation of DLOs that guide, enhance and amplify the cognitive processes of learners and aligned with the affective characteristics of learners. Such DLOs should facilitate learning.

6.1 Limitations of this study

Finally, it is important to identify some practical and theoretical limitations of this study. Firstly, the very small sample size was a significant limitation to this research. Despite the use of three data gathering instruments, the lack of quantitative data collected from the pre and post-assessments made it impossible to conduct any meaningful statistical analysis that identified the relationships between modality and learning. A larger sample size would have allowed for between groups analysis of the pre and post-assessment data. This would have contributed to the identification of any relationships between learning and modality. An additional limitation is that this study was not conducted in an authentic learning setting. None of the participants had to use the DLO as part of a course of study and participants used the DLO in a setting devoid of instructional context and facilitation. Ethical constraints may exist if similar research was conducted in an authentic course setting as participating learners may be exposed to DLO designs that are detrimental to learning while other participants may be exposed to designs that support learning. Careful experimental design would be required to address such issues. A third limitation of this study was the presence of high and low prior knowledge participants in each of the cases. The literature provides evidence of modality reversal effects due to the extent of the prior knowledge of learners. If a greater number of participants had of been available they could have been grouped based on the extent of their prior knowledge. This would have allowed for exploration of the relationships between modality and prior knowledge.

6.2 Recommendations for future research

Digital technology is ubiquitous in the 21st century and it is difficult to imagine a learner who has not had some previous experiences with digital learning objects, online learning environments or computer games. Consequently, DLO design is an emerging coherent discipline with an accumulating research base. Given the richness and sophistication of contemporary digital technologies, learners now bring these expectations of such DLOs with them to their learning. Powerful multimedia creation applications are commonly available and easy to use. These may tempt inexperienced instructional designers toward the production of DLOs that, although aurally and visually exciting, act to confuse and confound the learner and be detrimental to learning (Mayer, 2001, 2005, 2014; Moreno and Mayer, 2000; Moreno, 2006). I recommend that further study be devoted to exploring the interactions between human cognition, DLO design and learner characteristics in order to realise the creation of coherent, research-based guidelines that enable the creation of DLOs that support learning. The creation of such guidelines would provide educators and DLO designers the opportunity to fully exploit the power afforded by contemporary digital technologies and contribute to the realisation of the promise of ICTs for learning and teaching. CTML and CATLM provide evidence-based principles concerning learning from multimedia. These could be used as a basis for the proposed DLO design guidelines.

It is important to note that, as evidenced in the CATLM and CTML literature reviewed in this thesis, there exist discrepancies as to cause and effect of learning from multimedia. Consequently, further research is required that explores the principles of

CTML and CATLM in the context of DLO design. Areas for future research could include:

- Further investigation of the relationships between learners' affective and cognitive processes and learning from multimedia DLOs.
- Investigation of the application of the principles of CTML and CATLM to DLO design.
- The production of coherent evidenced based, DLO design guidelines.

Today, most educators use DLOs. However, pre-service teacher education training programmes and higher education teacher professional development courses do not typically consider the creation of learning materials from cognitive and affective perspectives. When the creation of learning materials is addressed in such programmes it is usually in the form of providing instruction on how to use a particular software application, for example, how to use Microsoft PowerPoint. As such there is a danger that teachers will invest time and energy in the creation of learning materials that are of little or no learning benefit. To this end, I recommend that pre-service teacher trainees be provided instruction concerning the application of multimedia design principles to the creation of learning materials. The advantages of this could include:

- Providing teachers with the skills and knowledge required for the creation of DLOs and other learning materials that support learning.
- Providing students with learning materials that support their learning.
- Making overt to teachers and educational organisations the educational benefits and resourcing requirements associated with DLOs designed for learning.

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Appendix 1: Case 1 (visual) results of Wilcoxon signed ranked test

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Pre	5	9.4500	1.62404	7.00	11.25
Post	5	12.5000	.50000	12.00	13.00

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
Post - Pre	Negative Ranks	0[a]	.00	.00
	Positive Ranks	5[b]	3.00	15.00
	Ties	0[c]		
	Total	5		

a. Post < Pre

b. Post > Pre

c. Post = Pre

Test Statistics[a]

	Post - Pre
Z	-2.023[b]
Asymp. Sig. (2-tailed)	.043

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Statistical significance

If the significant level is equal or less than .05 it can be concluded that the difference between the two scores is significant. In this case the significance level is .043. Therefore it can be concluded that the two sets of scores are significantly different. (Pallant, 2011).

Effect size

The effect size indicates the relative magnitude of differences between means. The effect size (r) for the Wilcoxon Signed Ranked Test is calculated by dividing the Z value by the square root of the sample size (N = n x 2) (Pallant, 2011).

In this case Z= 2.023 and N = 10 (5x 2) therefore r = 2.023/10 = 0.2

This indicates a medium effect size using Cohen (1988) criteria of .1 = small effect, .2 = medium effect, .5 = large effect.

Results summary

A Wilcoxon Signed Rank Test revealed a statistically significant increase in post-test scores following use of the visual DLO presentation design variant, $z = -2.023$, $p < .05$, with a medium effect size ($r = 0.2$). The median score on the post-test increased from the pre-test following use of the visual DLO design variant.

Appendix 2: Case 2 (audio variant) results of Wilcoxon signed ranked test

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Pre	4	11.8750	1.31498	10.00	13.00
Post	4	12.3750	.75000	11.50	13.00

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
Post - Pre	Negative Ranks	0[a]	.00	.00
	Positive Ranks	2[b]	1.50	3.00
	Ties	2[c]		
	Total	4		

a. Post < Pre

b. Post > Pre

c. Post = Pre

Test Statistics[a]

	Post - Pre
Z	-1.342[b]
Asymp. Sig. (2-tailed)	.180

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Statistical significance

If the significant level is equal or less than .05 it can be concluded that the difference between the two scores is significant. In this case the significance level is .180. Therefore it can be concluded that the two sets of scores are not significantly different. (Pallant, 2011).

Results summary

A Wilcoxon Signed Rank Test revealed no statistically significant increase in post-test scores following use of the audio DLO presentation design variant, $z = -1.342$, $p > .05$.

Appendix 3: Case 3 (audio-visual variant) results of Wilcoxon signed ranked test

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Pre	5	9.4500	1.62404	7.00	11.25
Post	5	12.5000	.50000	12.00	13.00

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
Post - Pre	Negative Ranks	0[a]	.00	.00
	Positive Ranks	5[b]	3.00	15.00
	Ties	0[c]		
	Total	5		

a. Post < Pre

b. Post > Pre

c. Post = Pre

Test Statistics[a]

	Post - Pre
Z	-2.023[b]
Asymp. Sig. (2-tailed)	.043

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Statistical significance

If the significant level is equal or less than .05 it can be concluded that the difference between the two scores is significant. In this case the significance level is .043. Therefore it can be concluded that the two sets of scores are significantly different. (Pallant, 2011).

Effect size

The effect size indicates the relative magnitude of differences between means. The effect size (r) for the Wilcoxon Signed Ranked Test is calculated by dividing the Z value by the square root of the sample size (N = n x 2) (Pallant, 2011).

In this case Z= 2.023 and N = 10 (5x 2) therefore r = 2.023/10 = 0.2

This indicates a medium effect size using Cohen (1988) criteria of .1 = small effect, .2 = medium effect, .5 = large effect.

Results summary

A Wilcoxon Signed Rank Test revealed a statistically significant increase in post-test scores following use of the audio-visual DLO presentation design variant, $z = -2.023$, $p < .05$, with a medium effect size ($r = 0.2$). The median score on the post-test increased from the pre-test following use of the audio-visual DLO design variant.

Appendix 4: User perception survey questions

Digital learning object evaluation survey

Mode: User's name will be logged and shown with answers

Working with the learning object has helped me learn.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

The interactivity of the learning object helped me learn.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

The multimedia features of the learning object helped me learn.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

The instructions in the learning object were easy to follow.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

The learning object was easy to use.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

The learning object is well organised.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

I liked the overall theme of the learning object.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

I found the learning object engaging.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

The learning object made learning fun.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

I would like to use the learning object again.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

What is your gender?

○ Male ○ Female

I am confident using information and communication technologies.

○ Strongly disagree ○ Disagree ○ Neutral ○ Agree ○ Strongly agree

What is your age?

Submit your answers

Appendix 5: Interview questions

- Has using the learning object helped you learn? Why? Why not?
- Why do you think it helped you learn?
- Did the interactivity of the learning object help you learn? Why? Why not?
- Did the multimedia features of the digital learning object help you learn? Why? Why not?
- Were the instructions about using the digital learning object easy to follow?
- Did you find the digital learning object easy to use?
- Is the digital learning object well organized? In what ways?
- Did you find the digital learning object engaging? Why? Why not?
- Did the digital learning object make learning fun?
- Did you like the theme of the digital learning object?
- What did you like about the digital learning object?
- What didn't you like about the learning object?
- What is your definition of a digital learning object?
- As a student do you use digital learning objects as part of your learning?
- What is your definition of learning?

Appendix 6: Information letters

Nicholas Ford
303 Hoon Hay Rd, Christchurch 8025
Email: nick.ford@canterbury.ac.nz
Phone: 021 257 8396

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

The Language of Science

Information Sheet for Participants

I am a Masters student at the College of Education, University of Canterbury and I invite you to participate in my study 'The Language of Science'.

The use of information and communication technologies (ICT) is an important and emerging theme in teacher education, professional development and teaching practice and the use of digital learning objects represents a component of ICT use in teaching and learning. This research project is representative of contemporary work occurring in this domain and is of relevance to pre- and in-service educators and learners.

This research will address the impact of digital learning object presentation design on learning performance by asking the questions:

- What are the implications of cognitive load theory for learning object presentation design?
- What are the relationships between learning object presentation design and learning performance?
- What are the relationships between learning object presentation design and learner perception of the benefits (or not) of learning objects?
- What are the relationships between learner perception of the benefits (or not) of learning objects and learning performance?

A proposal for this research has been submitted and approved by the School of Teacher Education, University of Canterbury.

For the last ten years I have worked in the field of teacher ICT professional development and support. I currently work at the University of Canterbury as a Flexible Learning Advisor in the Digital Media Group. I have also worked as a science teacher for years 9 -13 in New Zealand schools. My supervisors for this project are Dr Chris Astall and Dr David Winter, both of whom work as teacher educators at the College of Education, University of Canterbury. Both Chris and David are experienced science teachers.

If you agree to take part in this research you will be asked to do the following:

1. Complete a short online pre-test of approximately 10 minutes.
2. Use an online digital learning object at least once a week for 3 weeks. It is expected this will take about 5 to10 minutes each week.
3. Complete a short online post-test of approximately 10 minutes.

4. Complete a short online survey of approximately 10 minutes
5. Some participants will be invited to attend a group discussion at the College of Education that should last no longer than 40 minutes in duration.

Please note that participation in this study is voluntary and will have no impact upon your grades. If you do participate, you have the right to withdraw from the study at any time without penalty. If you withdraw, I will do my best to remove any information about you, provided this is practically achievable.

I will take particular care to ensure the confidentiality of all data gathered for this study. I will also take care to ensure your anonymity in publications of findings. All data will be securely stored in password-protected facilities and locked storage at the University of Canterbury for five years following the study. It will then be destroyed.

The results of this research may be reported internationally at conferences and in education journals. All participants will receive a report on the study.

If you have any questions about the study, please contact me at nick.ford@canterbury.ac.nz, phone: 021 257 8396.

Complaints may be addressed to the Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch, Email: human-ethics@canterbury.ac.nz
or my academic supervisors Dr Chris Astall (chris.astall@canterbury.ac.nz) or Dr David Winter (david.winter@canterbury.ac.nz).

If you agree to participate you will be asked to complete the online consent form.

Thank you for considering this request.

Regards

Nicholas Ford

Appendix 7: Consent form

Nicholas Ford
303 Hoon Hay Rd, Christchurch 8025
Email: nick.ford@canterbury.ac.nz
Phone: 021 257 8396

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CHRISTCHURCH NEW ZEALAND

The Language of Science

Student Consent Form

1. I have been given a full explanation of this project and have been given an opportunity to ask questions.
2. I understand what will be required of me if I agree to take part in this project.
3. I understand that my participation is voluntary and that I may withdraw at any stage without penalty.
4. I understand that any information or opinions I provide will be kept confidential to the researcher and that any published or reported results will not identify me.
5. I understand that all data collected for this study will be kept in locked and secure facilities at the University of Canterbury and will be destroyed after five years.
6. I understand that I will receive a report on the findings of this study. I agree to you using my University of Canterbury email details for this.
7. I understand that if I require further information I can contact the researcher, Nicholas Ford (nick.ford@canterbury.ac.nz).

If I have any complaints, I can contact Dr David Winter (david.winter@canterbury.ac.nz) or Dr Chris Astall (chris.astall@canterbury.ac.nz) or The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch, Email: human-ethics@canterbury.ac.nz.

By signing this form I agree to participate in this research project. Please include your email address and return this form to nick.ford@canterbury.ac.nz

Thank you.

Signature: ____

Email: ____

Appendix 8: Permission to adapt DLO

Hi Nick

Thank you for your email and you can use this diagram as per your request below.

The acknowledgment is The University of Waikato. www.sciencelearn.org.nz

I have added a download version of it here: http://www.sciencelearn.org.nz/Contexts/Flight/Sci-Media/Images/Forces-affecting-flight which you can use, this is the highest spec we have (750 x 500 pixels) and it is also attached for your convenience.

We would be most interested in seeing your interactive drop and drag and also in the results of your research if you would like to share it.

Are you aware of the other drop and drag interactives that we have on the site, i.e. http://www.sciencelearn.org.nz/Contexts/Flight/Sci-Media/Animations-and-Interactives/Wings-for-flight. Whilst this one is Flash, many of the others have been converted to HTML to work on mobile devices. I would be happy to send you a list if you are interested.

All the best with your Masters.

Regards

Vanya

Vanya Bootham
Project Manager

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www.sciencelearn.org.nz
www.biotechlearn.org.nz