A Framework for Mapping Multimedia to Educational Concepts

Chigozie Onyekaba

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Abstract

Multimedia provides exciting opportunities in education as it allows educational materials to be delivered in ways that can both simplify and enhance learning experience. Increasingly, educational material developers are using multimedia to deliver education but tend to use multimedia in ways that are more often based on intuition and personal experience, which can lead to the development of ineffective learning materials. It is known that some media types are better than others at conveying information. For example, when trying to portray a physical object, a picture would do a better job than text. This is a good illustration of the popular saying, “a picture is worth a thousand words”, but when is a word worth a thousand pictures, or when is an animation worth a thousand diagrams? The number of available media types, possible combinations and modes of delivery present a problem in the design of educational material. What media type(s) do we use for a given educational content to improve learning? This is important because using inappropriate media types can lead to the development of ineffective educational materials. The research aims to solve this problem. Initially, it presents the results of a study which shows that intuition and personal experience are mostly relied on, when developing educational materials. It then discusses the design of a media selection framework (the main contribution of this research) and a supporting web application. Next, it presents the results of evaluative experiments aimed at assessing whether learning was improved when the media selection framework was used. Modifications were made to the framework following the initial evaluation and the framework was re-evaluated. Statistically significant improvements in learning were observed when the framework was used. Finally, two case studies of multimedia development were presented to demonstrate the use of the framework.

Keywords: media, multimedia, media selection, hierarchical media taxonomy, information identifiers, media selection framework, educational concepts, educational materials.

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Publications

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1 Introduction

1.1 Introduction

Over the years, the use of multimedia (text, images, animations, audio and video) to deliver educational material has greatly increased and is now a popular means of delivering information (Li, Antonenko and Wang, 2019). This is because the technologies used to create and render multimedia have improved tremendously and are both easily accessible and cheaply available. Computers now have much faster central and graphics processors, multimedia software and technologies are more advanced, even the bandwidth for data transfer (which is crucial for multimedia) has increased massively. Multimedia provides exciting opportunities in education as educational material could be delivered in a multitude of ways, tuned to enhance learning. By using multimedia, educational materials can be presented in ways that both simplify and enhance learning. Increasingly, educational material developers are taking advantage of multimedia technology to deliver education. Schools now use virtual learning environments to deliver multimedia materials (such as Blackboard, Moodle, etc.) and students can now easily take online courses. However, educational material developers use multimedia in a variety of ways that are usually based on intuition and personal experience, and this could potentially have a negative effect on learning.

It is known that some media types are better than others in portraying some information or explaining some concepts. For example, when trying to present the definition of a word, text is probably the best media type to use, but when trying to portray a physical object, such as the look of a dog, a picture would do a much better job than text description. Let us illustrate this with a simple case. The next paragraph attempts to describe a garden.

“It is a beautiful garden with trees all around. The lawn is green and appears well-trimmed. There are some pink flowers to the left side of the garden. The sky appears overcast…”

Now which of the following images is being described? Figure 1.1 or 1.2?

Figure 1.1: A garden (source, http://tiny.cc/ust2cz)

Figure 1.2: Another garden (source, http://tiny.cc/kvt2cz)

As a matter of fact, it is anyone's guess. Although the description was based on the first image, both images match the description reasonably well. This is a good illustration of the popular saying, "a picture is worth a thousand words", but when is a word (or a sentence) worth a thousand pictures, or when is an animation worth a thousand diagrams?

The vast amounts of available media types, possible combinations and mode of delivery present a problem in the design of educational material. What media type (and mode of delivery, or modality) do we use for a given educational content? What media type and modality will result in improved learning for a particular educational concept? Selecting media for educational purposes should not be based on intuition or personal experience because selecting the wrong media type could result in a negative learning experience and that is what this research is all about. The aim of the research is to create a media selection framework that can be applied in the development of educational material with the goal of achieving as effective a learning experience as possible.

1.2 Background of the study

In the past, formal education had usually taken place in physical rooms with desks and chairs occupied by learners with at least one person carrying out the teaching duties, but computers have now revolutionized the entire educational process. It is now possible for education to be delivered, managed, even assessed by computers and this is referred to as electronic learning (e-learning). E-learning involves the use of computers (running specialised software) and electronic communication to deliver and manage learning. Multimedia is used in the delivery of learning and this form of learning has greatly increased in recent years (Srivastava, 2012). Many learning providers now use virtual learning environments (such as Blackboard and Moodle) to deliver educational materials. The benefits of multimedia learning cannot be overemphasised. They include, but are not limited to individualised/personalised learning, self-managed learning, self-paced learning, and interactive learning (Teoh and Neo, 2006). Other benefits of multimedia learning include helping students prepare themselves mentally (by having prior access to learning content) before receiving lessons, supporting a tutor during teaching activities, supplementing the learning activities, etc. Due to the huge potentials that multimedia and e-learning hold for education, there has been an increase in research work in around multimedia.

A lot of research work has focused on the media types used to deliver education and how they affect the learning process. Many researchers generally agree that multimedia improves learning and that it is a great alternative to traditional methods of learning (Butcher, 2014; Mayer, 2003; Moradi, Khazai, and Moradi, 2017; Najjar, 1998; Pate and Posey, 2016; Schnotz and Kulhavy, 1994; Sweller, 1999; Tway, 1995), and as a result, researchers have been exploring various ways to take advantage of multimedia in educational delivery. Even more recently, there is evidence that certain multimedia types can stimulate certain emotional responses from learners (Lee, Hsiao and Ho, 2014). Research has shown that the mode of multimedia delivery (referred to as modality) can also influence learning. For example, it has been suggested that people learn better when (in an electronic multimedia material that employs the use of texts and images) on-screen texts are replaced with audio narrations. Researchers refer to this as the modality effect (Herrlinger, Höffler, Opfermann and Leutner, 2017; Low and Sweller, 2005; Mayer, 2009; Moreno and Mayer, 1999; Sweller, van Merriënboer and Paas, 1998). In explaining this phenomenon, references have been made to Clark and Paivio's (1991) dual coding theory which postulates that humans generally process information through two channels. These are the verbal (auditory) and non-verbal (for example, visual) channels. When learners learn through a single channel, for example, visually, more demand is placed on memory but utilising both channels when learning usually leads to improved learning. Whilst this theory is generally accepted, it was found that there are situations where the modality effect is diminished, for example, when learners are allowed more time to learn. Tabbers, Martens, and van Merriënboer (2001) found that using images with on-screen text can be as effective as using images with audio narrations when learning tasks are not time-controlled by the system. This was also observed by Harskamp, Mayer and Suhre (2007) when they repeated the modality experiment in a science class. Following that experiment, they noted the conditions in which the modality effect will be observed, one of which is when the learner does not have extra time to learn. Other observations which have been noted to affect (or influence) learning are the coherence effect (exclusion of extraneous media), spatial contiguity effect (placement of descriptive text very close to images) and personalisation effect (increasing social presence in multimedia, such as polite wordings) (Mayer, 2009; Clark and Mayer, 2016). As a result of these, some guidelines for the design of educational multimedia materials have been documented.

Bhowmick, Khasawneh, Bowling, Gramopadhye and Melloy (2007) have noted the growing evidence which suggests that some media combinations appear to be more effective than others in helping people learn. Sahasrabudhe and Kanungo (2014) have also noted that learning domain could play a role in the selection of appropriate media. In general, it can be said that the choice of multimedia is key to effective learning. Research findings by Bhowmick et. al. (2007) confirm that the choice of media type is crucial, even more so when dealing with complex learning tasks. Unfortunately, educational multimedia design and the selection of media is usually driven by intuition and personal experiences (Holmquist and Narayanan, 2002). The importance of getting media selection right cannot be overemphasised because improper application of media can have an adverse effect on the learning experience. There is therefore a need for a methodical approach to media selection for educational multimedia, which educational material developers can use, rather than relying on intuition or personal experiences.

Attempts have been made in the past to create methods for the choice and selection of media (for example, Heller, Martin, Haneef and Gievska-Krliu, 2001; Sutcliffe, Kurniawan and Shin, 2006; Sun and Cheng, 2007; Alsadhan, Alhomod, and Shafi, 2014), however, some of these have been more of a general approach to media selection in user interface designs and some haven’t taken into account the vast amount of media types available. This therefore presents the need for a method-based approach towards selecting relevant media types for educational delivery. This approach should be one such that every learning task should map to a unique media type (or types) and modality in the educational material. Such a method should produce an optimal map between an educational concept and the media types used to create the learning material for that educational concept, such that learning from the resulting educational material should be very effective.

1.3 Aims and objectives

The main aim of this research is to develop a framework for the selection and application of appropriate media types in the design of learning material, such that utilising this media selection framework will result in an optimal learning experience. The objectives for the research are outlined as follows: -

1. Conduct a literature review on current multimedia design theories and the practical application of multimedia to interface design.
2. Carry out a study to understand how media selection is currently done.
3. Develop a set of rules for the hierarchical classification of media types.
4. Develop a media selection framework and application.
5. Design and conduct experiments to evaluate the media selection framework.
6. Make any necessary improvements to the framework based on the outcome of the evaluation and re-evaluate the media selection framework.
7. Develop case studies to illustrate the use of the media selection method developed.
8. Write up the research thesis.

1.4 Theoretical basis

There is a general consensus among researchers that the use of multimedia in the delivery of educational instruction enhances learning (Butcher, 2014; Mayer, 2003, 2009; Moradi, Khazai, and Moradi, 2017; Najjar, 1998; Pate and Posey, 2016; Schnotz and Kulhavy, 1994; Sweller, 1999; Tway, 1995). Mayer (2003) refers to this as the promise of multimedia and goes on to say that learning which leads to problem-solving transfer can be improved with the use of words and pictures (multimedia). This is usually referred to as the multimedia principle and this research is underpinned by this very multimedia principle. Researchers have also observed that the mode of delivery of the multimedia used to create a learning material improves learning. It is now known that people learn better when on-screen text in a multimedia learning environment is replaced with audio narration, when combined with images or animation (Herrlinger, Höffler, Opfermann and Leutner, 2017; Jeung, Chandler and Sweller, 1997; Low and Sweller, 2005; Mayer, 2009; Moreno and Mayer, 1999; Sweller, van Merriënboer and Paas, 1998). This is referred to as the modality effect. One explanation for this has to do with the dual coding theory proposed by Clark and Paivio (1991) which postulates that visual information (such as on-screen text, images, and animations) and verbal information (such as an audio narration) are processed in different channels. This is because when the learner has to make sense of the images and at the same time read on-screen text during the learning process, the visual processing channel is overloaded while the auditory channel is unused, leading to cognitive overload but when both the visual and auditory channels are used simultaneously, cognitive load is reduced (Hughes, Costley and Lange, 2019). The modality theory will inform this research. Other theories which this research will be based on are the contiguity principle which advocates that words should be aligned to corresponding images and the redundancy principle which advocates the removal of on-screen text where there is an audio narration of the text (Clark and Mayer, 2016).

1.5 Scope of the research

One of the main issues this research attempts to address is how we select appropriate media types to represent educational concepts with the goal of achieving optimal learning. In trying to solve this problem, the research focuses on the media types that are used in the development of educational materials, their information presenting attributes and capabilities and what kinds of educational concepts are best represented by the media types. As we know, learners differ in needs and requirements, for example, some learners may have certain needs such as visual needs, accessibility requirements, hearing requirements, etc. The research does not focus on these. These are areas that would be suitable for future research.

1.6 Ethical considerations

Ethics is a very important as aspect of research. The UKRI defines research ethics as “the moral principles and actions guiding and shaping research from its inception through to completion, the dissemination of findings and the archiving, future use, sharing and linking of data” (UKRI, n.d). When research involves participants, the first step of the research process is the consideration of ethical issues around the research and to obtain ethical approval (Molich, Laurel, Snyder, Quesenbery, and Wilson, 2001). As this research involves the use of human participants at several stages, ethical approval was sought from the University’s ethics committee. A proportionate ethics review form was completed. The University’s proportionate ethics review form is used where the research poses only minimal ethical risks, and “focuses on minimally sensitive topics, entails minimal intrusion or disruption to others, and involves participants who would not be considered vulnerable in the context of the research”. The research was conducted in accordance with the requirements of the proportionate ethical review process. All participants were given sufficient information about the research and had to sign a consent form. They were also given the opportunity to ask questions about the research and they were provided with an email address to contact, should they want to learn more about the outcome of the research or if they wanted their data to be removed from the research.

1.7 Expected outcomes

- A literature review on educational multimedia history and existing design frameworks.
- A framework for the selection of appropriate media in the development of educational materials.
- A media selection application which is based on the framework.
- Contribution to the discourse around the effects of adapting an educational material to a learner's preference and/or style.
- Case studies demonstrating the use of the framework.

1.8 Expected contributions to knowledge

The advantages of a well-designed learning material cannot be overemphasized. When people learn from properly designed materials, they understand better and faster, retain what was learned for longer, and apply the skills learned much better. Proper use of multimedia in educational creates the conditions for optimal learning to occur. This is what Mayer (2003) refers to as the promise of multimedia. The creation of educational materials by intuition can lead to poorly designed learning materials, which may inhibit learning, retention, and knowledge application. Although there are some guidelines for the use of multimedia, some of these guidelines do not quite precisely and/or methodically specify what media type or types to use for the selection of multimedia materials for a given educational concept. The main contribution of this research to the body of knowledge is a novel framework for the selection of media in the design of learning materials. This will bring very important benefits to learning and educational multimedia development because the framework will foster the development of well-designed learning materials that make appropriate use of multimedia, thereby further enhancing learning, retention, and knowledge application. It will be possible to apply this framework in many educational fields. The research will also outline a process for organising media types into hierarchies, which will be useful in not just the media selection framework but possibly in other contexts. This is a minor contribution from the research and will be referred to as a hierarchical media taxonomy. A software application will also be developed for the purpose of easing the application of the media selection framework to educational material design. Other contributions that are likely to emerge from this research are a further confirmation of the benefits of multimedia to learning and education, a better understanding of how to design educational multimedia and contributions to the discourse around the effects of adapting an educational material to a learner's preference and/or style.

1.9 Structure of the thesis

This thesis contains eleven chapters. A summary of each chapter is provided as follows: -

Chapter 1 (Introduction): This chapter introduces the research. It discusses the background of the research, the aims and objectives, theoretical basis, the research approach, the expected outcomes, and the research contributions.

Chapter 2 (Literature Review): This chapter reviews current research in the field. It discusses a brief history of educational multimedia, learning theories (behaviourism, cognitivism, and constructivism), learning preferences (such as Kolb's model, Honey and Mumford and the VARK model) and the criticisms of learning preferences, multimedia design theories and then leads into the research question, highlighting the need for a methodical approach to media selection.

Chapter 3 (Research Methodology): This chapter sets out the research methodology and approach that will be utilised in this research. It outlines the research approach, the different stages of this research and the methods that will be utilised in each stage.

Chapter 4 (Current Approaches to Media Selection): This chapter discusses a survey aimed at understanding how media selection is currently done in practice. The chapter discusses the findings from the survey.

Chapter 5 (A Hierarchical Media Taxonomy): This chapter discusses the definition of media and multimedia and then discusses a hierarchical media taxonomy which aims to structure media types into hierarchies so that they can be used in the media selection framework.

Chapter 6 (Media Selection: An Initial Design): This chapter proposes a media selection framework, discusses the development of a media selection application and then presents a simple example of how media selection could be done, using the framework and the application.

Chapter 7 (Media Selection: An Initial Evaluation): This chapter discusses experiments aimed at evaluating the proposed media selection framework. The validation experiment assessed whether learning was improved when the framework was used, the reliability experiment assessed whether users were able to use the framework to correctly select media and the usability experiment assessed the usability and ease of use of the framework and the software application. The results and implications were discussed.

Chapter 8 (Media Selection: Improvements): This chapter discussed some improvements which were made to the framework based on user feedback from the initial evaluation. The chapter also discussed the development of a new software tool which incorporates the functionalities that were added following the feedback received.

Chapter 9 (Media Selection: Re-Evaluation): This chapter discusses the experiments aimed at re-evaluating the improved media selection framework. The validation experiment assessed whether there were still learning improvements after the modifications to the framework and the usability experiment assessed the usability and ease of use of the framework and the new software application. The results and implications were discussed.

Chapter 10 (Case Studies of Multimedia Development): This chapter presents two case studies that were aimed at illustrating the media selection framework and how it could be applied in the development of educational multimedia materials. An evaluation of the multimedia materials was also discussed.

Chapter 11 (Research Evaluation and Conclusion): This chapter summarises the research. It discussed the research contributions, the problems encountered, the limitations and highlights some suggestions for future work.

2 Literature Review

2.1 Introduction

It is widely accepted that learning is improved when multimedia is used in education (Najjar, 1998; Mayer, 2003, 2009; Butcher, 2014; Pate and Posey, 2016; Moradi, Khazai, and Moradi, 2017, etc). The availability of computers with fast internet connections and huge storage capabilities has brought about the possibility of developing highly effective and easily accessible learning environments (Sahasrabudhe and Kanungo, 2014), thereby resulting in an increase in multimedia-related research (Srivastava, 2012). Researchers have constantly sought ways to utilise multimedia to enhance education and improve learning experience. As a result, a number of theories about the use of multimedia have emerged, for example, modality effect, coherence principle, redundancy principle, personalisation principle, and contiguity principle (Clark and Mayer, 2016), Heller's Multimedia Taxonomy (Heller, Martin, Haneef and Gievska-Krliu, 2001), Multimedia User Interface Design (Sutcliffe, Kurniawan and Shin, 2006), Sun and Cheng's (2007) media richness theory-based approach, etcetera. Although some of these theories focus on the effects of multimedia on the learning process and how best to take advantage of multimedia, there is not sufficient knowledge about what media type or types are suitable for presenting information about a given educational concept, in the development of multimedia learning materials. As a result, educational material developers tend to create learning content intuitively and/or based on their individual experiences (Holmquist and Narayanan, 2002), however, relying on individual or personal experience could potentially have adverse effects on learning experience, especially if the designer is inexperienced in educational multimedia design. For example, a well-designed interface that makes use of inappropriate media types may end up inhibiting learning, instead of enhancing it. In addition to this, educational multimedia designs may differ very widely between designers because individual experiences differ. This chapter sets out the basis for the research programme. It begins by discussing a brief history of multimedia in learning and education, some learning theories, and models, and some of the relevant multimedia theories that have emerged and are useful to this research. It also discusses some multimedia design methods and the problems that these methods do not adequately address. It ends with a discussion of why there is a need for a methodical approach to educational multimedia design.

2.2 Brief history of Educational Multimedia

Multimedia is everywhere around us, from the smartphones in our hands, to the computers we use daily at home, school, and work. Today's world would simply be a different place without multimedia. The use of multimedia in education predates modern times, for example, the Christian apostle, Paul in the first century, educated members of the church using textual epistles, many of which are recorded in the religion's books. Text of course, is one of the many media types used in multimedia education. For hundreds of years, education had been delivered through face-to-face lectures and books. As technology began to appear, the use of video tapes via post began to gain traction around the 1970s and the delivery of education via satellite began to emerge in the 1980s. It wasn't until the invention of the internet and the world wide web that multimedia use in education exploded. Between the 1970s and the 1990s, researchers began to study the conditions under which multimedia might enhance learning, and how learners construct mental representations of educational materials. Today, the use of multimedia in education is widespread as researchers have found that it can be an effective way to deliver learning, and this has led to even more research into the use of multimedia in education, from which many theories have emerged.

2.3 Learning theories

Learning can be said to be the process of acquiring knowledge, skills or behaviours. This could involve either new knowledge or a modification of existing knowledge. The act of learning can be traced back to life origins. Humans, animals and even plants (Karban, 2015) learn to make sense of everything in their environments. New-born babies learn to recognise faces and voices, they learn to walk, talk, and ultimately, they learn to learn. Learning has (directly and indirectly) resulted in the technological advancements in our world today. Resulting from research about the learning process, several theories about learning have emerged. These theories include behaviourism, cognitivism, and constructivism. In the following sections, some of these theories are briefly discussed.

2.3.1 Behaviourism

Behaviourism is an approach to learning that is based on the belief that learning occurs as a response to external stimuli (Skinner, 1974). The behaviourist believes that knowledge is external to the individual and that learners must be provided with the necessary external experience for them to learn. Such learning becomes evident as acquisition of new behaviour or behavioural changes in the learner. The behaviourist believes that learning can be achieved by the use of reinforcement and punishment techniques. Learning also occurs through classic conditioning (Pavlov, 1927), operant conditioning (Skinner, 1938) and social learning (Bandura and Walters, 1963). The behaviourist approach to learning was criticised for not considering cognitive processes. This gave rise to the cognitivist approach to learning.

2.3.2 Cognitivism

Cognitivist approaches to learning emerged as a response to the criticisms of the behaviourist approach. Cognitivism involves the process of thinking and acquiring knowledge. This approach to learning looks at the entire mental process. It is sometimes referred to as cognitive psychology. In cognitive learning, the focus shifts from external behaviours to mental processes involving thinking and the use of memory. Bruner (1961) proposed that rather than being about the acquisition of knowledge, learning is a development of conceptual knowledge, cognitive skills, and strategies. Cognitive learning theories also include the concept of meta-cognition. This is generally defined as “knowing about knowing” or learning about the cognitive process. Metcalfe and Shimamura (1994) defined it to include knowledge about the use of strategies for learning or problem-solving. Moving on from cognitive approaches to learning, constructivist approaches have gained popularity.

2.3.3 Constructivism

Constructivism is based on the postulation that learners play an active role in the learning process by constructing knowledge for themselves using prior knowledge and experiences and this approach of learning is usually recommended by cognitivists (Duffy and Cunningham, 1996). Cognitivists believe that a good understanding of what is already known by the learner is needed to create effective learning schemes. Active learning and discovery learning have both emerged from cognitivist approaches to learning.

2.4 Learning styles and models

In consideration of how people learn, researchers have come up with several competing theories that suggest that people differ in the way they learn. Such individual differences are referred to as learning styles. This is widely accepted by many practitioners but not without criticism. Research into different styles of learning can be traced back to the 1950s and grew in popularity from the 1970s (Coffield, Moseley, Hall, and Ecclestone, 2004). Various learning style models have emerged, and the next sections briefly reviews some of the most commonly used learning styles or models.

2.4.1 Kolb's Model

Kolb's learning style model is one of the most frequently used models (Dağ and Geçer, 2009) and it is derived from experiential learning theory which is essentially the process of learning through experience (Kolb and Fry, 1975). Kolb's model stems from two approaches that involve the grasping of experience (Concrete Experience and Abstract Conceptualization) and two approaches that involve the transformation of experience (Reflective Observation and Active Experimentation). From these, four learner modes were produced which are: -

- Accommodator: A combination of concrete experience and active experimentation. People with this style are usually strong in practical tasks.
- Converger: A combination of abstract conceptualization and active experimentation. People with this style are usually good in the application of theories.
- Diverger: A combination of concrete experience and reflective observation. People with this style tend to display imaginative strengths.
- Assimilator: A combination of abstract conceptualization and reflective observation. People with this style tend to show strength in developing theories and inductive reasoning.

To facilitate the process of identifying learning styles, an assessment known as the Learning Style Inventory is used to group learners into one of these four categories. Although this learning style is widely accepted, there has been some evidence showing that it may need to be revisited and redesigned (Manolis, Burns, Assudani and Chinta, 2013). Smith (2013), in a compilation of criticisms of Kolb's model, stated six issues with Kolb's model. These are as follows: -

1. The model does not adequately address the process of reflection.
2. The model makes extravagant claims.
3. It does not sufficiently address different cultural situations.
4. It has weak empirical evidence.
5. It overly simplifies the relationship between learning processes and knowledge.
6. The model does not necessarily match reality.

2.4.2 Honey and Mumford

Following on from Kolb's work, Honey and Mumford (1982) developed four learning styles which were derived from Kolb's learning cycle but using them in managerial contexts. These learning styles are: -

- Activist: They involve themselves fully and without bias in new experiences.
- Reflector: They like to stand back to ponder experiences and observe them from many different perspectives.
- Theorist: They adapt and integrate observations into complex but logically sound theories.
- Pragmatist: They are keen on trying out ideas, theories, and techniques.

A learning style questionnaire (2006) was developed to provide a simple way to determine an individual's learning style. This questionnaire also contains more description about the four different learning styles.

2.4.3 VARK Model

The VARK Model was developed by Fleming (2006) based on work earlier done by Barbe (1979). The VARK model utilises sensory modalities to group individuals into categories that represent how they best learn. These four modalities are Visual, Auditory, Read/Write and Kinaesthetic. The visual preference uses media types like maps, images, diagrams, and charts to depict information that could have otherwise been written in text form. Visual learners tend to prefer visual learning (learning that takes place through visual channels) and as such, they prefer to learn using media types such as charts and diagrams. Auditory learners prefer to learn from spoken words or using communication means that is “heard”. These include speeches, discussions, and lectures. Read/Write learners learn best by reading text while kinaesthetic learners prefer to learn by doing exercises or practicing the concepts being learned. According to Fleming and Mills (1992), kinaesthetic learners are “connected to reality either through concrete personal experiences, examples, practice or simulation”. Kinaesthetic learners prefer to learn using videos, demonstrations, and simulations. A website, vark-learn.com, was designed to ease the classification of people into their respective learning models. The questionnaire hosted on the website contains 16 multiple choice questions and users can select more than one option for each question if there are more than one option matching their perception and in the same way, they can ignore questions that do not apply to them (although they have to respond to a minimum number of questions to get a result). After submitting the answers to the questions, the user is told what his/her learning preference is, which would be one of visual, aural, kinaesthetic or read/write. In some cases, your preference may be a combination of two or more of these categories (multimodal). While most learning styles were designed around the process of learning and how individuals (learners) generally participate in the learning activity, the VARK model is based on sensory modalities which is, in some way, related to type of media that is used to deliver the learning. For example, a visual learner would prefer to learn using visual media types such as charts and diagrams, and not media types based on other sensory channels such as audio. Although the VARK model does not specify what media type or types each learner would need to use, it tends to separate individuals into categories that are based on their preferred channel, that is, the sensory channel through which learning is most effective for them. The fact that the VARK learning model is based on sensory modalities makes it an appropriate model to embed in a media selection framework that places focus on media types used to represent information, how that information is processed by learners, and through what channels.

2.5 Criticisms of Learning Styles

The use of learning styles has not been without criticism. Many scholars have questioned the basis for categorising individuals based on their style of learning and some researchers have found little or no empirical evidence to support the idea of learning styles. Massa and Mayer (2006) carried out some experiments but said that there was not strong support for the hypothesis that different learners (for example, verbal and visual) should be given different kinds of multimedia instruction. Willingham (2009) stated that for a learning style theory to be valid, it must consistently attribute one person to the same style, show that people with different styles learn and think differently and show that people with different learning styles do not differ in ability. He however found that none of the learning style theories met every one of these criteria. Kirschner and van Merrienboer (2013) stated that learning styles produce a poor classification of learners, and one reason is because in most cases, the differences between individuals are gradual and not nominal. Another problem with learning styles is that many of them rely on self-assessments when the learning style of an individual needs to be identified. This is usually done by means of a questionnaire (for example, Honey and Mumford’s Learning Style Questionnaire and the VARK online questionnaire) but self-assessments are usually regarded as an unreliable means to take an objective measurement and one reason is because people are often unable to or not willing to accurately report what they do or feel they would do (Kirschner, 2017) and such inaccuracy causes the learning style classification to change from assessment to assessment. One study that demonstrates the unreliability of self-assessments is that of Rawson, Stahovich and Mayer (2017). In this study, students were given a smart pen (which recorded usage data) and asked to do some homework. They were subsequently asked to report when and how long they spent doing their homework. The researchers found that they were differences between what the students reported and what the smart pen recorded. In one of the cohorts, 88.5% of the participants reported figures that were much higher than what their smart pens recorded (average overestimation of about 19 hours). One other argument against self-assessment is the question about whether people really know what is best for them within the context of learning. Knoll, Otani, Skeel and Van Horn (2017) also stated that learning styles are built on the subjective aspects of learning. Some of the issues raised with the theory of learning styles are about how the learning style experiments are designed. Pashler et. al. (2008) stated that to test learning style hypotheses, a particular kind of study is required. They stated that participants must be grouped into the learning styles that are being tested and then randomly assigned one learning method so that some participants would have a learning method for their style and others would have a different learning method not for their learning style. At the end, participants must write the same test and if the hypothesis is correct, there should be a difference between the performance of those matched to their learning styles and those matched to a different style. They noticed that most of the experiments on learning styles did not adopt this approach and those that did, except for one, obtained negative results. Kirschner (2017) summarises his report by saying that there is no real scientific evidence to support the notion that an individual has an optimum learning style, can reliably identify such a style, and that optimum learning occurs when learning instruction is tailored to that person’s learning style. Researchers are divided on the usefulness of learning styles so more work may be needed to better understand the conditions under which they work (or do not work), something that this research will attempt to contribute to at a later stage.

2.6 Learning and Multimedia

Learning is said to be an active process involving the filtration, selection, organisation, and integration of information (Grech, 2018) and the use of multimedia in the process of learning has greatly increased in recent years. This is because learning is deeper when multimedia is used, compared to traditional methods of learning (Mayer, 2003; Butcher, 2014; Pate and Posey, 2016; Moradi, Khazai, and Moradi, 2017, etc). This is often referred to as the multimedia effect. Learners can now take courses and learn very effectively from virtually anywhere, using multimedia applications such as learning management systems, intelligent tutoring systems and virtual learning environments. Examples of such systems are Blackboard, Moodle, Brightspace, etc. The use of multimedia in education brings with it a lot of benefits, which include personalised learning, self-managed and self-paced learning, etc. (Teoh and Neo, 2006). A significant amount of research work has focused on multimedia and its effect on the learning process and as a result, various theories about the use of multimedia have emerged. One such theory suggests that people learn better when on-screen text is replaced with audio narrations. This is referred to as the modality effect (Moreno and Mayer, 1999; Low and Sweller, 2005; Mayer, 2009; Herrlinger, Höffler, Opfermann and Leutner, 2017). An explanation for this is that higher demand is placed on working memory when the learners have to joggle reading text and viewing images to create a unified mental representation of them. The modality effect can also be explained by the dual coding theory (Clark and Paivio, 1991), which is based on the postulation that humans generally process information through two channels (verbal and non-verbal). It is known that little information can be processed in one channel at a time (Sweller, Ayres and Kalyuga, 2011) and that the working memory has limitations in terms of capacity and duration, compared to long-term memory which is unlimited (Anmarkrud, Andresen and Bråten, 2019; Sweller, van Merriënboer and Paas, 2019). Therefore, when both channels are utilised simultaneously, learning is usually improved because there is more capacity to process information. Although the modality effect is generally accepted by many researchers, it was found not to apply in every situation (Tabbers, Martens and Van Merriënboer, 2001). The researchers were able to show that in a non-system paced environment, images with on-screen text can be as effective as images with audio narrations. The modality effect therefore becomes less observable when learners are allowed more time to learn. This experiment was repeated (Harskamp, Mayer and Suhre, 2007) and the modality effect was still observed. However, the conditions under which the modality effect applies were noted. One such condition is when the learner is not allowed extra time to learn, corresponding with earlier findings. The multimedia effect which is observed when learning with multimedia can also be explained on account of the integrated model of text and picture comprehension which proposes that mental models are constructed more from pictures than from text (Schnotz and Bannert, 2003; Schnotz, 2005).

Multimedia research has produced several theories such as the modality effect (replacing words with narrations), coherence principle (exclusion of extraneous media), redundancy principle (removal of redundant material such as text which accompanies spoken words), personalisation principle (increasing social presence in multimedia, such as polite wordings) and contiguity principle (placement of descriptive text very close to images) (Clark and Mayer, 2016), however, not much is known about what specific media type is suitable for a given learning concept. Although it is known that learning is improved when multimedia is used, one cannot assume that any combination of media will automatically result in improved learning (Grech, 2018), even when pictures are added to text (Herrlinger et. al., 2017), as the multimedia principle advocates. There is evidence that some media types and/or combinations appear to be more effective than others in enhancing learning. For example, Bhowmick, Khasawneh, Bowling, Gramopadhye and Melloy, 2007) observed that there are combinations of multimedia that result in better learning than others, particularly as the complexity of the learning task increases. Klenner (2015) also stated that semiotic systems (image, text, audio, video, etc) have advantages and disadvantages which means that some are more suitable in some media contexts than others. Sahasrabudhe and Kanungo (2014) also showed from their study that media choice plays a role in the effectiveness of learning, however, they said that this relationship also depends on the learning domain and learner's learning style. Therefore, it can be said that the choice of media in the development of educational material is key to effective learning. It is no longer enough to say that multimedia improves learning, rather we should be asking, what types of media improve learning and for what educational concepts? The importance of using appropriate media cannot be overemphasised because improper use of media can have an adverse effect on learning experience (Wang, Fang and Gu, 2019).

2.7 Multimedia design theories

Some guidelines for the selection of media have been produced in the past. For example, Heller, Martin, Haneef and Gievska-Krliu (2001) proposed guidelines for mapping some information types to media types (text, sound, graphics, and motion). The information types used were: - concrete, abstract, spatial temporal, quantitative and covariant relationship. Sutcliffe, Kurniawan and Shin (2006) also proposed a method for the design of multimedia interfaces and media selection. The researchers provided advice on media selection based on a set of communication goals which include generalised tasks such as "explain", "warn", "excite" and "attract". One problem with these guidelines is that they do not adequately take into account the vast number of media types, particularly subtypes that are available. For example, Heller's multimedia taxonomy framework (Heller et. al., 2001) made use of only four main media types which are motion, graphics, sound, and text. Another problem is that some of these guidelines, for example, Sutcliffe, Kurniawan and Shin (2006) were designed for use in the development of general user interfaces and are not especially suited to educational requirements. Sun and Cheng (2007) examined the use of Daft and Lengel's media richness theory (1986) in educational multimedia design and found it to be useful in the design of some educational materials, however, it could be argued that classifying media as being high or low in richness says very little about its suitability for a given educational concept. It could also be argued that relying on the ‘richness’ of media may inadvertently lead to the use of an unsuitable type of media which can have adverse effects on learning (Bartsch and Cobern, 2003). Alsadhan, Alhomod, and Shafi (2014) proposed a method for the design and integration of multimedia in e-learning which was loosely based on the waterfall software development methodology, however, the method does not have a strategy for precisely selecting media for educational materials, thereby leaving a lot to the designer in terms of the media type to use which can lead to the selection of inappropriate media types (when the user is inexperienced). In the next few sections, these multimedia design theories are reviewed, and some criticisms are highlighted.

2.7.1 Heller's Multimedia Taxonomy

Heller et. al. (2001) proposed a multimedia design framework which was, in practice, a way to get users to think about the questions relating to how multimedia should be designed. The taxonomy was presented as a three-dimensional matrix consisting of the media types (text, sound, graphics, and motion), the media expressions (elaboration, representation, and abstraction), and the context (audience, discipline, interactivity, quality, usefulness, and aesthetics). The media type dimension is where decisions about the media types are taken. These are the media types available. The media expression dimension defines the extent to which the media type is represented. The information on the media may be elaborate (with a lot of detail), representational, or a presented with some form of abstraction. The context dimension was provided because multimedia does not exist in a vacuum but is consumed by an *audience*, within a *discipline* and is *interactive* in nature. It is also judged based on its *usefulness*, *quality,* and *aesthetics*.

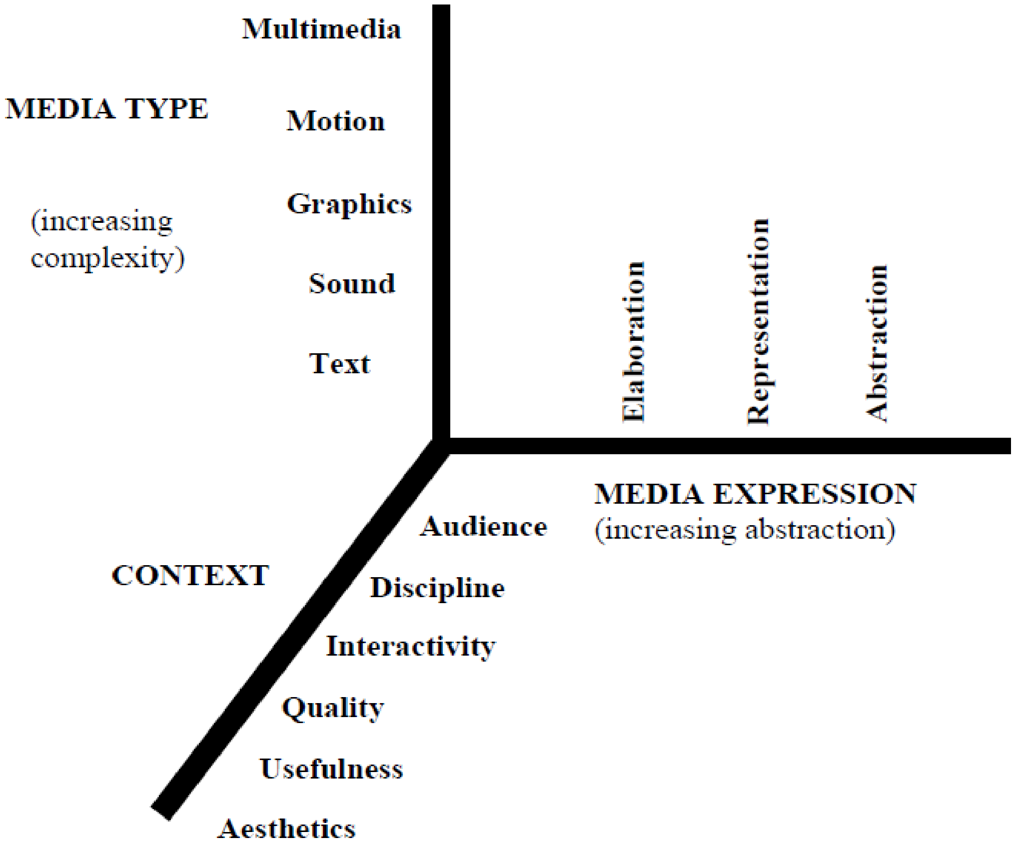


Figure 2.1: Heller's Multimedia Taxonomy

The idea behind this taxonomy was to organise multimedia and simplify its use. While this was a useful step towards solving some of the problems associated with the design of multimedia which involves the choice of media, the aim was mainly to draw attention to difficult issues, leaving a lot of decision making to the users. The author also highlighted that multimedia takes on different characteristics, depending on the audience. For example, multimedia intended for educational purposes would have different characteristics compared to multimedia intended for computer interaction or navigation. One of the problems with this approach is that it only takes into consideration a very small set of media types (motion, graphics, sound, and text) but it can be argued that there are more media types than these four, especially when media is considered at sub level, for example, what kind of motion?

Animation or video? It also allows a lot of room for subjectivity when designing multimedia materials. This is because the intention of the author was to prompt questions about the multimedia design to be generated, such as “Is the font size appealing?”, “Are the icons appealing?”, “Is the sound too noisy or annoying?”, etc.

2.7.2 Media Richness Theory

Media richness theory is based on the notion that different media types have varying capacities for information presentation. This theory was proposed by Daft and Lengel (1986) and was derived from information processing theory. Daft and Lengel set out four criteria for sorting media types in order of its richness. These criteria include the ability of the medium to transmit cues, obtain immediate feedback, use natural language, and have a personal focus. Based on these criteria, face to face media were regarded as being high in richness and text was regarded as being low in richness. Sun and Cheng (2007) applied the media richness approach to the design of multimedia for e-learning and designed an experiment to examine its effectiveness. They found that learning trails that had a high degree of "uncertainty and equivocality in content" required rich media representations but there were ineffective for courses with low content uncertainty. This finding seems to lend support to findings by Bhowmich et. al. (2007) which suggests that for complex learning tasks, the choice of media is very crucial, or to summarise, the greater the complexity of the learning task, the greater the need to choose the media types more carefully. While this approach provokes some thought about the way educational multimedia design should be approached, it does not answer the question of what media type to use for what educational concept. The “richness” of a media type does not say anything about the suitability of that media type for that educational concept or learning task. For example, videos may have high capacities for presenting information, but would a video be a suitable replacement for a chart? It could also be argued that relying on the ‘richness’ of media may inadvertently lead to the use of irrelevant media which can have adverse effects on learning (Bartsch and Cobern, 2003).

This could potentially also lead to the violation of the redundancy principle of multimedia (Hoffman, 2006) which advocates for the removal of redundant material. In addition to this, the increased cognitive overhead that comes with an increase in media richness can lead to a decrease in learning (Acha, 2009).

2.7.3 Sutcliffe's Multimedia User Interface Design Method

Sutcliffe et. al. (2006) developed what they called a design advisor which was targeted at novice designers. This was based on a premise that media selection should be based on information types and communication goals. The process of using the method begins with requirements and information analysis, the purpose of which is to determine the content and communication goals. This is then fed into the media selection stage. A decision tree was used in determining the information types. It begins with identifying whether the information is about something physical or conceptual, followed by questions whether the information is about something that changes (dynamic) or does not (static). At this stage, some information types are presented which are based on definitions usually found in software engineering. In addressing the issue of media selection, Sutcliffe et. al. (2006) presented a set of what was referred to as communication goals or tasks. These tasks are Explain, Persuade, Warn, Excite and Attract. These tasks are supplemented with more guidelines for using media. Information types were also presented and were mapped to media types. The media types used in this information types to media types mapping are realistic audio, non-realistic audio, speech, realistic still image, non-realistic still image, text, realistic moving image, non-realistic moving image, and language-based media. They also highlighted the preferred choice for each information type and scenario. The authors also presented some heuristic guidelines to supplement the information-to-media mappings. While this method makes some advances towards the goal of guiding users to a suitable media type for the intended purpose, some problems arise. Some of these are: -

1. Few media types were used. While it is clearly not feasible to exhaust the list of media types currently available, it could be argued that a list of only nine media types is too small to provide sufficient robustness for a method and/or tool which is to be used for designing multimedia. This is even more so, considering that the method does not provide a mechanism for extension or adding other media types.

2. There is too much room for subjective interpretation. It could also be argued that the more the subjectivity involved in the media selection process, the greater the risk that an inappropriate media type would be selected. Although, this would be much less likely with experienced users, it is more likely to happen with inexperienced users.

3. This method was designed for general user interfaces and while this may be suitable for some educational purposes (for example, it was evaluated by developing a crowd control training system), it could be argued that a method which is more focused towards education and learning would be more suitable in the design of educational material, than a generalised method.

2.7.4 Waterfall-based Multimedia Design Model

Alsadhan, Alhomod, and Shafi (2014) proposed a method for the design and integration of multimedia in e-learning. This method was loosely based on the waterfall software development methodology. The model consists of three phases. These are the multimedia content modelling, multimedia content development and multimedia content integration phases. The phases are subdivided into a total of seven activities (analysis, design, technical requirements, content development, content production & integration, implementation, and evaluation).

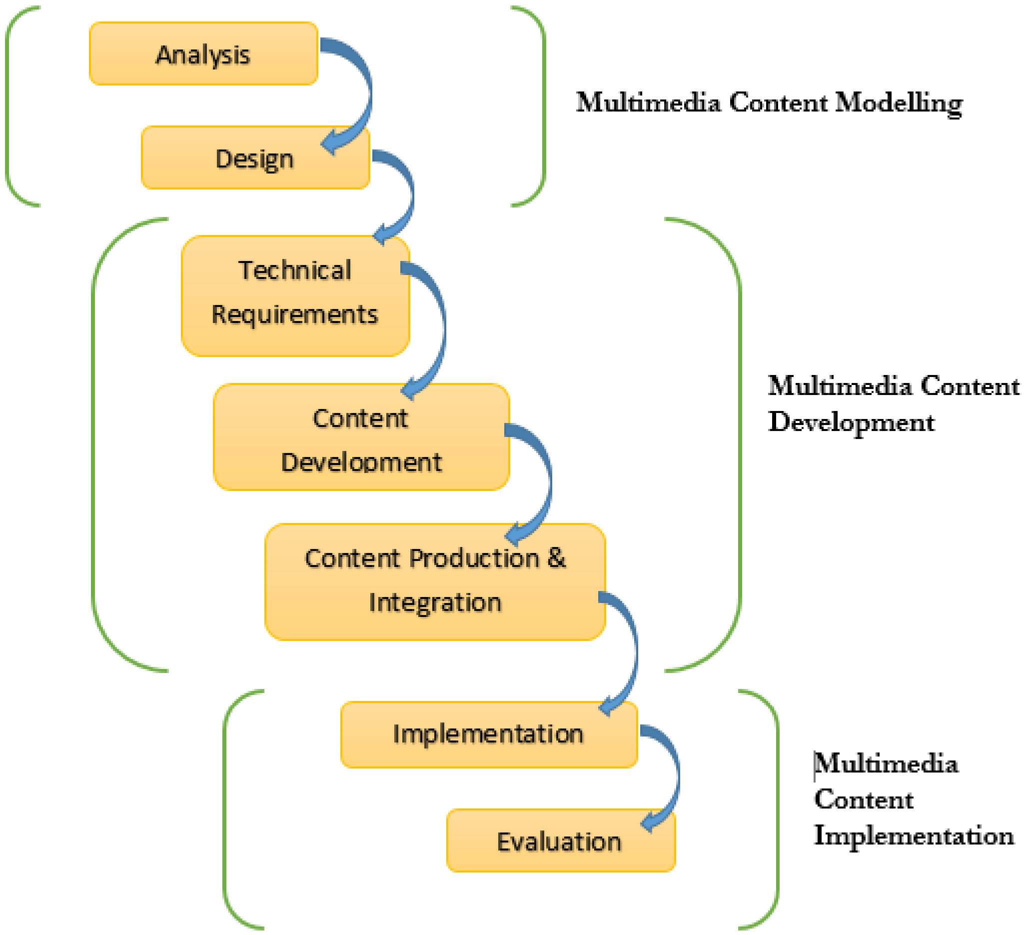


Figure 2.2: Waterfall-based multimedia design method

In the design stage, the media types to be used for the e-learning are identified, which is based on the learning objectives (also defined in the stage). These media types are then used to create story boards during the content development stage and these story boards define everything that will be displayed on screen and played out as audio. Each story board outlines the text, graphics, audio, animation, and video that will be used for the e-learning creation. In the content production stage, the media definitions contained in the story boards are then produced and assembled. The main limitation to this approach is that it does not have a process which governs the precise selection of the media types used. This means that users of this method will be able to choose any media type they consider suitable which could equally lead to the wrong use of media.

2.8 The need for a methodical approach

Researchers agree that the application of multimedia theory in education can improve learning (for example, Mayer, 2003, 2009; Butcher, 2014; Pate and Posey, 2016; Moradi et. al., 2017), that certain media types do better in presenting educational information than others (for example, Bhowmick et. al., 2007; Sahasrabudhe and Kanungo, 2014), and that the use of inappropriate multimedia material may result in no learning (Chen and Sun, 2012), however, there is not yet a methodical approach for selecting a media type or combination of types to present information for a given educational concept. While there are a number of approaches to media selection (such as Heller's multimedia taxonomy, the application of Daft and Lengel's media richness theory by Sun and Cheng (2007), and Sutcliffe's multimedia user interface design method), most of these utilise only a small subset of media types, allow for much subjectivity in the selection process or are only guidelines for media utilisation. There is therefore need for a media selection framework for educational multimedia, which incorporates the media types frequently used in the design of educational material and is sufficiently methodical with less room for subjectivity. It is expected that such an approach would lead to improved learning by eliminating the issues that could arise from improperly following guidelines/heuristics or issues that could arise from relying on intuition in the development of educational materials.

2.9 Summary

This chapter began by briefly discussing the history of educational multimedia. Following on from that, relevant learning theories such as behaviourism, cognitivism and constructivism were discussed. The chapter also discussed some learning styles such as Kolb's model, Honey and Mumford's learning style and the VARK learning model, and some of the criticisms of learning styles. The chapter then proceeded to discuss the application of multimedia in education and some multimedia theories (such as the modality effect, redundancy principle, coherence principle and contiguity principle). While multimedia is known to improve learning, there is evidence that the multimedia design itself, in particular, the media types used, have an effect on the learning effectiveness. Four multimedia design theories were also reviewed. These were Heller's multimedia taxonomy which was presented as a three-dimensional matrix consisting of media types (text, sound, graphics and motion), media expressions (elaboration, representation and abstraction), and context (audience, discipline, interactivity, quality, usefulness and aesthetics), the application of media richness theory to the design of educational multimedia, Sutcliffe's multimedia interface design method which maps information types (obtained through the use of a decision tree) to media types and the waterfall-based model for the design and integration of multimedia in e-learning, proposed by Alsadhan, Alhomod, and Shafi (2014). The need for a methodical approach to educational multimedia design cannot be overemphasised as it would lead to improved learning experiences for learners. The next chapter sets out the research methodology and approach that will be utilised in this research.

3 Research Methodology

3.1 Introduction

In the previous chapter, the history of multimedia, relevant learning theories and multimedia design theories were discussed. The chapter highlighted some of the problems that could arise when improper media is used in educational materials and why there was a need for a methodical approach to media selection. This chapter sets out the research methodology and approach that will be utilised in this research. It begins by presenting an overview of research methods and methodology and then goes on to outline the research approach, the different stages of this research and the methods that will be utilised in each stage.

3.2 Overview of research methods and methodology

A research methodology can be defined as the systematic way in which a research is conducted, such as the techniques employed in data gathering, the way in which the data is analysed, interpreted, and how conclusions are drawn about that data. A research methodology can also be thought of as the blueprint of a research (Murthy and Bhojanna, 2009). The choice of research methodology is a very important decision when conducting research as the validity of the results (or new knowledge) obtained in a research activity rests on the chosen methodology. A research methodology does not just involve the methods applied to research, but also the values, theories and principles that underpin the research approach (Somekh and Lewin, 2005). There is often a confusion between research methodology and research methods. In research, these terms are somewhat related, but they mean different things. Method can be referred to the procedure for gathering and analysing data and the specific techniques used to analyse and extract information from the data (for example, the statistical analysis used). Methodology, as described earlier, is the systematic way in which the research is conducted. Birks and Mills (2015) defined methodology as “a set of principles and ideas that inform the design of a research study.” The upcoming sections in this chapter describe the chosen research methodology and methods.

3.3 Research approach

The methods used in conducting research lay the foundations that underpin the research’s validity. Not using the correct method or approach puts the results of any research on weak foundations. There are two approaches commonly used in research. These are quantitative research and qualitative research. Quantitative research involves the empirical investigation of quantitative phenomena through the collection, analysis, and interpretation of data. Statistical analysis is usually performed on the data collected. Qualitative research usually involves collecting data in form of words. Usually, the goal is to understand human behaviour and what governs such behaviour. It is a subjective research method and participants must be chosen carefully.

Although this research takes a largely quantitative approach, this research also contains qualitative elements and therefore can be said to have adopted a mixed-methods approach (a mix of quantitative and qualitative approaches). The next section discusses each stage of the research, the research methods adopted and the reasons for adopting the chosen methods.

3.4 Stages of the research

The research aims to develop a framework for the selection of appropriate media types in the development of educational materials and will begin with a review of existing multimedia design frameworks and multimedia theories. Following the literature review, the following are the key stages of the research: -

3.4.1 Understanding current approaches to media selection

This stage of the research involves a primary study carried out understand how media types are selected in the development of educational materials. This is an important stage as the data collect would not only be useful in gaining an understanding of current approaches to media selection in the development of educational materials but may also help provide some insight and context to how the problem could effectively be solved. A survey will be developed for this purpose and will be distributed to representative respondents (respondents such as lecturers who are involved in educational materials development). The study adopts a mixed methods approach in that the survey will not only contain questions that could be analysed statistically, but also text boxes would be provided for respondents to provide any comments they might have. The benefit to this approach is that a survey is very easy to administer, and the data could be very quickly analysed. The provided text boxes for additional comments will also make it possible to gain extra useful information about current approaches to media selection.

3.4.2 Development of a media taxonomy

This stage of the research takes an evaluative approach (as it forms the basis for a new approach to the media selection problem) and it involves the development of a set of rules for the hierarchical classification of currently known and future media types. These rules are then used to create a hierarchical classification of some common media types used in the development of educational multimedia. The first step in this stage involves the identification of currently known commonly used media types which could be used in the development of educational materials. Following on from that, the relationships between these media types will be evaluated and findings will be used to formulate the rules that would be used to create a hierarchical media taxonomy. The hierarchical media taxonomy would then be used in the development of the media selection method and framework.

3.4.3 Development of the media selection framework

This stage involves the development of the media selection framework. The key aim of the research is to develop a framework for the selection and application of appropriate media types in the design of learning materials, such that utilising the framework will result in an optimal learning experience. In this stage, the information presenting attributes/capabilities of media types will be evaluated. The essence of this is to investigate what kinds of information and/or concepts each media type will be great at conveying. This stage employs an evaluative research method as the intention here is to create a methodical approach for media selection. Information identifiers will be created and will be mapped to the most suitable media types for conveying these kinds of information. The process for selecting media types for the creation of educational materials will also be detailed.

3.4.4 Development of a media selection software application

Following on from the development of the media selection framework, a media selection application will be developed. A software application is needed in order to eliminate the possibility of human error in the media selection process and to simplify the task of performing a media selection. The application will be web-based so that it can be accessible from a browser, without the need for installation onto a specific computer. The application will be subjected to usability evaluation to ensure that it is usable. The usability evaluation will utilise both a qualitative and a quantitative approach. Modifications and/or improvements to the application may be necessary following the usability evaluation.

3.4.5 Evaluation of the media selection method

Given that the aim of this research is to develop an educational media selection framework, the use of which should result in optimal learning, it is important that such a framework is evaluated to ensure it meets its goals. A quantitative research approach will be used in the evaluation of the media selection framework. The evaluation process will involve creating (or modifying an existing) educational material using the framework, getting learners to learn using the educational material created by the application of the framework and then measuring learning performance by means of a leaning test. In essence, two educational materials created from the same concepts will be used. One will be a pre-existing learning material, and the other will be a learning material that was developed using the media selection framework. Learners will be put into two groups with similar capabilities and experiences. One group will learn using the pre-existing learning material while the other will learn using the material created through the application of the media selection framework. Both groups will then be asked to complete a learning test. An independent samples t-test analysis will be performed (using SPSS) to compare the test scores of both groups. This test was judged to be appropriate because the aim of this experiment is to assess whether there is a statistically significant difference in learning test outcomes when learners learn from a material that was created though the application of the framework, compared to a pre-existing learning material. If the media selection framework is valid, then the expectation is that the group that learned with material developed using the media selection framework will perform (statistically significantly) better in the learning test. Other aspects of the framework will also be evaluated, such as how easy it is for people to learn to use the framework and to employ the framework in the development of multimedia material.

3.4.6 Illustrative case studies

Case studies are very useful in research and usually involve the detailed study of a particular phenomenon. During case studies, data may be collected and analysed but typically, case studies involve observation. There are different forms of case studies. One of it forms, known as an illustrative case study, deals with the demonstration of something to illustrate a thesis or principle. In this stage of the research, two illustrative case studies will be run to illustrate the use of the media selection framework in the development of educational materials. Learners will be asked to evaluate the learning materials used in the case studies and some feedback will be obtained from the learners about what they think of the multimedia material.

3.5 Summary

In this chapter, the research methodology and approach for this research was set out. An overview of research methods and methodology was discussed, the research approach outlined, and the different stages of the research were also outlined. The next chapter discusses a study which was carried out to understand how educational material developers select and use multimedia in the development of educational materials.

4 Current Approaches to Media Selection

4.1 Introduction

Multimedia is widely used in the development of educational materials, in fact, it would not be possible to produce any educational material without the most basic use of media, that is, the use of text. In previous chapter, the importance of using multimedia correctly in the development of educational materials was discussed. The need for a methodical approach to the selection of multimedia for educational material was also highlighted. Also, we now know that there is little information about what media type (or types) is suitable for presenting information about a given concept, in the development of multimedia learning materials. Although we know that educational material developers tend to create learning content intuitively and/or based on their individual experiences (Holmquist and Narayanan, 2002), only very little evidence is available to support this statement. Moreover, it is very important to understand how media selection is currently done by practitioners, in order to understand how this can be improved upon, to ensure that learning is as effective as can be. This chapter therefore presents a survey which explores how educational material developers create the educational materials they make available to learners. In particular, focus was placed on participants who have some lecturing or teaching experience as these are one set of people who regularly develop learning content. This chapter discusses the survey design, the results and the conclusions drawn from the survey.

4.2 The Experiment

The purpose of the experiment presented here is to understand how educators approach the design of the educational materials they deploy. An online survey was created for this purpose and was distributed to people who identified as lecturers, teachers, and educational material developers. The respondents were asked questions about how they normally design educational multimedia materials (such as PowerPoint slides for lectures/lessons, web-based learning materials, PDF learning materials, books, educational videos, etc.) and what multimedia design methods they followed (if any).

4.3 The Design

Survey as a data gathering technique is commonly used in many fields of research and when developed and implemented properly, it can be a very effective way of gathering data. Depending on the method used, it can also be a cheap way of gathering information. As it is a proven means of gathering data, it was decided that a survey would be used to gather data for this study. In particular, an online survey was chosen as it was much easier to administer (via email) and very accessible for respondents. This means that respondents can respond to the survey questions in a relaxed environment without the need to set up a face-to-face or activity such as an interview. Also, the data that was sought could easily be obtained in a survey, hence a survey was chosen. The survey (questionnaire) contained questions which were aimed at understanding how the participants develop educational materials. For example, the respondents were asked whether they normally follow or adhere to any multimedia design methods or principles (be it in full or in part) when they design educational materials and if yes, what methods were used. The respondents were also asked questions about whether they were consistent in the use of the methods they said they adhered to and whether there was an observed improvement in learning experiences for their learners. In general, all participants were asked to give some information about how they design multimedia materials such as lecture slides, videos, books, etcetera, how they select media for the educational materials, and how their chosen media types were judged to be right for the intended purpose. Finally, all participants (regardless of whether they adhered to any multimedia design method or not) were asked whether (or not) they thought that adhering to a multimedia design method or principle could lead to improved learning experiences for their learners. The survey was developed using Google Forms and a sample of the online survey form is provided in the appendix section.

4.4 The Respondents and Procedure

The respondents were individuals who identified as lecturers, teachers, and educational material developers. It was necessary for this to be the case because the aim of this study is to gather information from individuals who are involved in learning design on a regular basis, or as a profession, and lecturers and teachers fit into that category very well. Given that the research was being done in Staffordshire University, it was decided that lecturers from the University would be used as participants, as there may be a higher tendency to respond when contacted by a researcher (using a known email domain name) within the same institution. It was also easy to obtain a list of lecturers and their contact details (email addresses) from the University's staff directory. Careful considerations were given to the use of only lecturers from within the University and it was judged not to be a potential source of bias as there were no specific methods of educational multimedia design in enforcement at the University at the time. In essence, lecturers were free to choose how they design their materials. An email with a link to the survey was sent to over 600 participants (lecturers) from a range of schools (Computing & Digital Tech; Health & Social Care; Law, Policing & Forensics; Life Sciences & Education; and Business & Economics). The participants had to consent to participation before they were able to access the questions in the survey. There was also the provision for the participant to contact the researcher to get more information about the study such as the results or the outcome, or to withdraw from the study (even after completion of the survey).

4.5 The Results: Descriptive statistics

There were 35 respondents to this survey (5.8% response rate). Over 50% of the respondents were between the age of 25 and 44. Except for one, all respondents were 64 years or less and no respondent was less than 25 years old. Except for one respondent who chose not to provide this information, all respondents were educated up to bachelor’s level (20.6% were bachelor’s degree holders, 55.9% were master’s degree holders and 23.5% had a doctorate degree). The respondents had an average teaching experience of 12 years, and the average number of years of experience in educational multimedia design was 11.5. Over half of the respondents (54.3%) admitted that they do not follow any multimedia design method when designing educational multimedia. About a quarter of the respondents (25.7%) said that they sometimes follow a multimedia design method while one fifth (20%) said that they followed a multimedia design method. These are shown in figure 4.1.

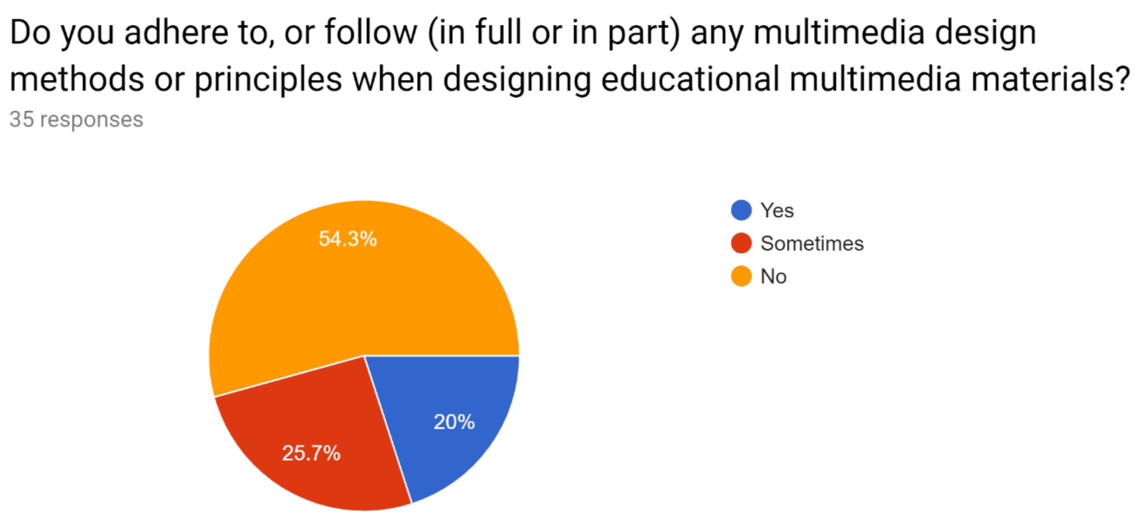


Figure 4.1: Multimedia design adherence

Those that answered yes or sometimes to this question were asked to provide more information about the educational multimedia design methods that they use. Subsequently, they were asked if the use of their chosen educational multimedia design method led to better learning experiences for their learners. To this question, 62.5% of respondents agreed that there were better learning experiences observed and 25% of the respondents thought that their methods led to better learning experiences only some of the time. These are also shown in figure 4.2. Crucially, no one thought that there was no observable improvement in learning experiences (although two respondents added notes to their responses which are also shown in figure 4.2).

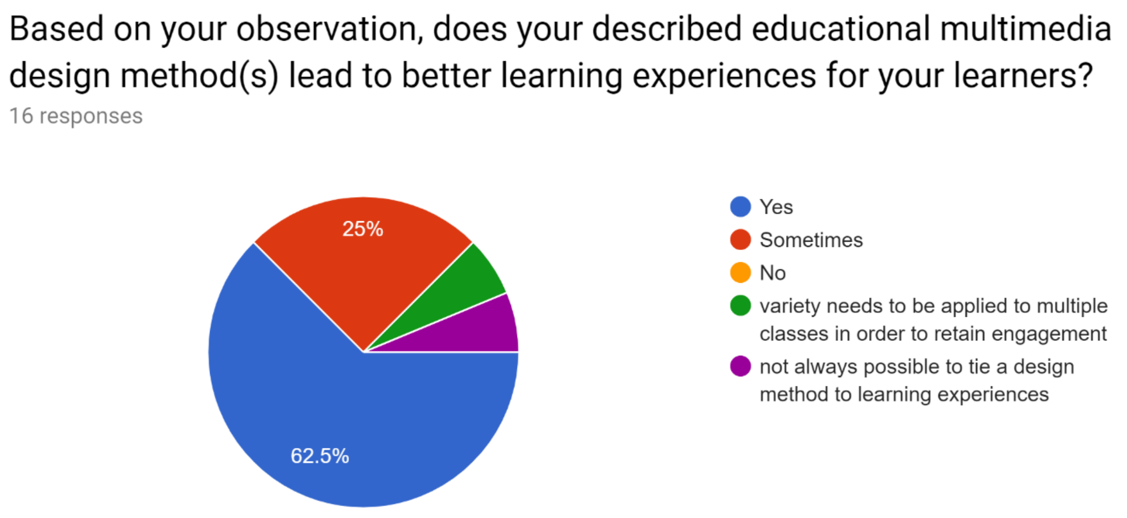


Figure 4.2: Multimedia design method – learning experience observation

More generally, participants were asked whether they agreed that using an educational multimedia design method could lead to improved learning experiences for their learners. Just over half of the respondents (51.4%) thought so, however, the remaining respondents (48.6%) were either unsure or neutral about it. These are shown in figure 4.3.

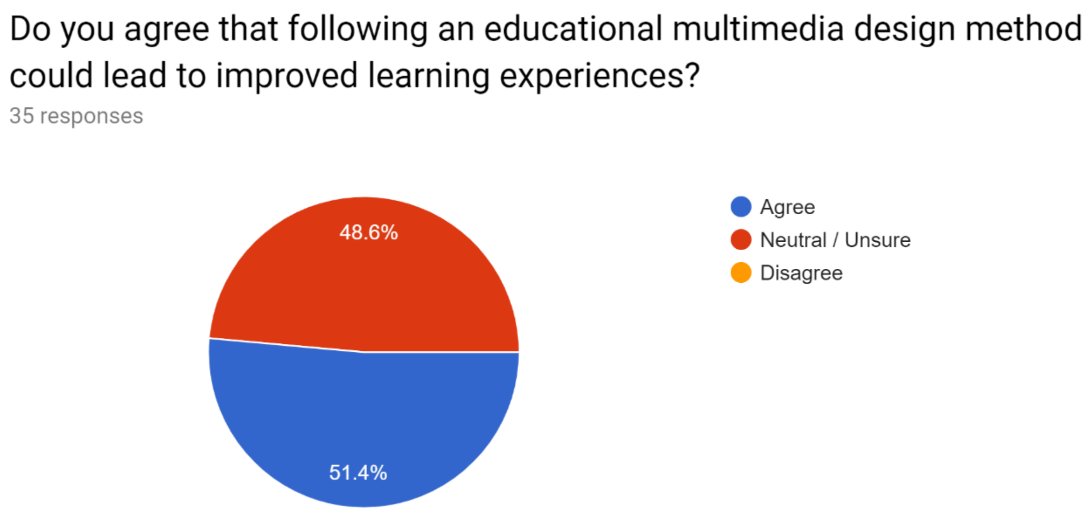


Figure 4.3: Multimedia design method – learning experience improvement

4.6 Discussion

One very important observation from this survey was the weak understanding of what a multimedia design method really is. Just under half of the respondents (45.7%) said that they (always or at least sometimes) adhered to or followed (in full or in part) multimedia design methods or principles when designing educational multimedia materials, but when asked what methods they used, many of the responses were not multimedia design methods but rather, the tools that they used to create and/or deliver the educational materials. For example, five respondents listed Microsoft PowerPoint as the multimedia design method that they use but we know that Microsoft PowerPoint is not a multimedia design method but rather, a tool used to create electronic presentations on slides (pages). Other respondents listed a few media types that they normally use when designing educational materials (for example, charts, pictures, videos, graphics, etc.) without details about how they would choose (or the decision process that guides choosing) these media types. In all responses, there was no mention or discussion of a known method or framework for multimedia design and certainly none that provides a method or process for the selection of media types for educational multimedia. Two respondents wrote that they tend to limit the use of text, with one saying that they minimise text and maximise graphics, however, information was not provided as to why and when text should be limited, and graphics maximised.

Of those who responded that they follow a multimedia design method, 56.3% said that they follow a method consistently when they design multimedia materials, with the rest saying that they do not do so consistently. An interesting observation is that 87.5% of these respondents agreed that based on their observation, the methods they followed (at least sometimes) lead to better learning experiences for their learners (although to keep the survey simple, they were not asked how the improvement in learning experience was measured).

Every respondent (including those that said they did not adhere to or follow any multimedia design methods or principles) was asked to give details about how they design educational multimedia materials. Most of the respondents said they use Microsoft PowerPoint and Adobe PDF to design educational materials (again providing information about the tools and means of delivery) but did not give many details about how they decide which media types to use. Some respondents said they keep the materials concise and that they limit the use of text. One respondent said they use "bold, simple, elegant slides/PDF materials, keep [materials] concise, provide further reading, always have images and examples to back up ideas". They also said they "always limit the visual words and keep the info for later reading by student". Another respondent said "I think of what I want to include in the slides, start off with the title slide and decide the title, then just go through and add bits that I think would be of interest to the student. I add and delete bits as I am doing it, and usually the process takes a few weeks on/off, doing bits every day. I google images that I think would add to the presentation". One thing that is obvious from the responses is that there is not a clearly defined method being followed in the development of educational materials.

Moving on, the respondents were asked more directly, how they ascertained that they have selected the correct media type for the intended purpose. A number of respondents said that they get other people to review or proofread their materials. Others said they listen to feedback from students and peers. Some respondents (about 38% of them) were very plain in saying that they simply rely on intuition, personal judgment, and experience, using responses like “I just use what I believe will be more effective in passing knowledge to my students”, “I tend to use my judgement”, “Intuition and experience” and “from experience”. The responses to this question could be roughly grouped into the following categories: - Intuition and experience, soliciting feedback (from those using the materials, for example, students), peer review (getting a peer to review the materials) and other (for example, no response or no validation of materials). 18 responses (51.4%) were related to intuition and experiences, 10 responses (28.6%) were related to feedback, 3 responses (8.6%) were related to peer review and 4 responses (11.4%) were related to other. From this, it becomes clear how much intuition and experience are relied on, when developing educational materials, just as was mentioned by Holmquist and Narayanan (2002). Following on from this question, the respondents were asked whether they agreed that using an educational multimedia design method could lead to improved learning experiences to which no one disagreed. 51.4% said they agreed with the statement and 48.6% said they were unsure or neutral about it.

4.7 Summary

This chapter presents a study which was conducted to find out how educational material developers such as teachers and lecturers select the media types that they use in the materials they develop. The chapter discussed the experiment design, the respondents, and the results. One thing that became obvious from the results was that many educational material developers at the forefront of learning and education do not tend to follow or adhere to any educational multimedia design method. It also became obvious that some educational material designers do not also understand what a multimedia design method is. Now, we know that relying on intuition increases the chance of incorrect application of media, particularly for inexperienced users, which we know can lead to poor learning experiences. This is something that over half of the respondents admitted that they do. Many of the respondents relied on loose guidelines (such as using less text and more graphics) with no justification provided. For example, it may be okay to reduce text in some scenarios but not all the time as there may be situations when text is just the right media type. The same goes for maximising graphics, for example, static graphics may be no good in demonstrating how an engine work. The results of this study highlight the need for a methodical approach to media selection for educational multimedia. Relying on intuition and personal experience could potentially lead to the development of ineffective educational materials that would create negative experiences for the learners. The next chapter discusses a media taxonomy which is the first step taken in this research, towards creating a framework for the selection of media in the development of educational materials.

5 A Hierarchical Media Taxonomy

5.1 Introduction

The last chapter presented the results of a survey aimed at understanding how educators develop educational materials. Of most interest is the process of selecting media types during the development of educational materials. One thing that became obvious from the results is that a lot of educators rely on intuition and personal experiences during the development of educational materials, which supports the statement made by Holmquist and Narayanan (2002). Relying on intuition and personal experience can potentially lead to the development of ineffective educational multimedia materials, therefore it is important that there is a methodical approach to media selection in the development of educational materials. As a first step, it is important to have a good understanding of is media itself. What is media? What is multimedia? How many media types are there? How can it be organised to make it easier to use or apply in a media selection method? This chapter presents a discussion of media itself and presents a taxonomy which organises media types in a hierarchical manner so that it can be used in a media selection method.

5.2 What is Media and Multimedia?

Media can mean many different things, for example, a means of mass communication (such as tv, radio and newspapers), a form of storage for computer files (such as hard disk, tape drives and compact discs) and could also be referred to how information or data is stored. There is often confusion surrounding the terms media and multimedia. The term media is sometimes used to refer to instructional or information delivery methods. Sugrue and Clark (2000) highlighted two sources of confusion with the term media, one of which was a lack of distinction between media itself and the methods used to present or deliver media. Kozma

(1991) described media as a resource that possesses information presenting attributes or capabilities. These resources are usually used for instructional purposes or to convey general information. Examples of resources with information presenting attributes are video, text, audio, and graphics. Multimedia can therefore be said to be a combination of these resources with information presenting attributes or as Heller et. al. (2001) described, a seamless integration of them. Other definitions of multimedia include “the use of multiple forms of media in a presentation” by Schwartz and Beichner (1998), “a combination of text, graphics, animation, pictures, video, and sound to present information in a coherent manner” by Singh (2003), and “the integration of media such as text, sound, graphics, animation, video, imaging into a computer system” by Jonassen (2000). In this research, resources with information presenting attributes are referred to as media types and this is in line with ISO’s definition, which refers to media as “different specific forms of presenting information to the human user” and multimedia as “combinations of static and/or dynamic media which can be interactively controlled and simultaneously presented in an application” (ISO, 2002). It should also be noted that this research refers to media as a singular item (although the term media is the plural form of the word medium). Multimedia can therefore be said to refer to more than one media. The term media and media type are also used interchangeably in this research. Having defined what media and multimedia are, the next natural question to ask might be how many media types are there? Interestingly, there are not a lot of main media types (such as video, text, audio, and graphics) but when considered at subtype level, there are (or can be) quite a lot, and given the vast amount of multimedia materials available, which incorporate a lot of multimedia components (or media types), there is a need to identify and classify these media types. At least, it would not be possible to develop any framework or method for selecting multimedia for educational materials without knowing, at least to some extent, what media types are available for such framework or method to utilise. The next section presents a hierarchical media taxonomy for the classification of media types, which defines a simple set of rules that allows anyone to classify any existing or new media type.

5.3 Hierarchical Classification of Media

There are lots of media types available and with new media types being developed occasionally, it may not be feasible to identify all available media types. This presents the need for media types to be group into categories that make them easier to work with. For this purpose, a hierarchical media taxonomy has been developed. The hierarchical media taxonomy imposes an inheritance-like relationship between media types, like the inheritance relationship that exists between super classes (base classes) and sub classes (derived classes) in object-oriented programming. It begins with a super (or base) media type called ‘Media’ which is the parent of all media types. The sub types of Media are Image, Animation, Text, Video and Audio. Just as a sub class has an ‘is a’ relationship with a super class in object-oriented programming, the sub types of media have an ‘is a’ relationship with Media. Therefore, an Image *is a* Media (type) and a Video *is a* Media (type). Sub types of Image will also have an ‘is a’ relationship with Image and with the super type of Image, which is Media. This taxonomy also uses hierarchical level numbers to highlight the position of a media type, relative to the media type at the top of the hierarchy, Media. The media type, Media, is at level 0. Direct sub types of Media are at level 1 (for example, Image). Sub types of a level 1 media type are at level 2, and so on. This hierarchical structure also allows for the use of terms such as parent, child, ancestor, and descendant. The parent of a media type is the media type immediately above that media type in the hierarchy and the child of a media type is the media type immediately below that media type in the hierarchy. An ancestor is any media type that sits anywhere above the reference media type and has an ‘is a’ relationship with it while a descendant is any media type that sits anywhere below the reference media type and has an ‘is a’ relationship with it. Figure 5.1 shows the hierarchical structure of some common media types.

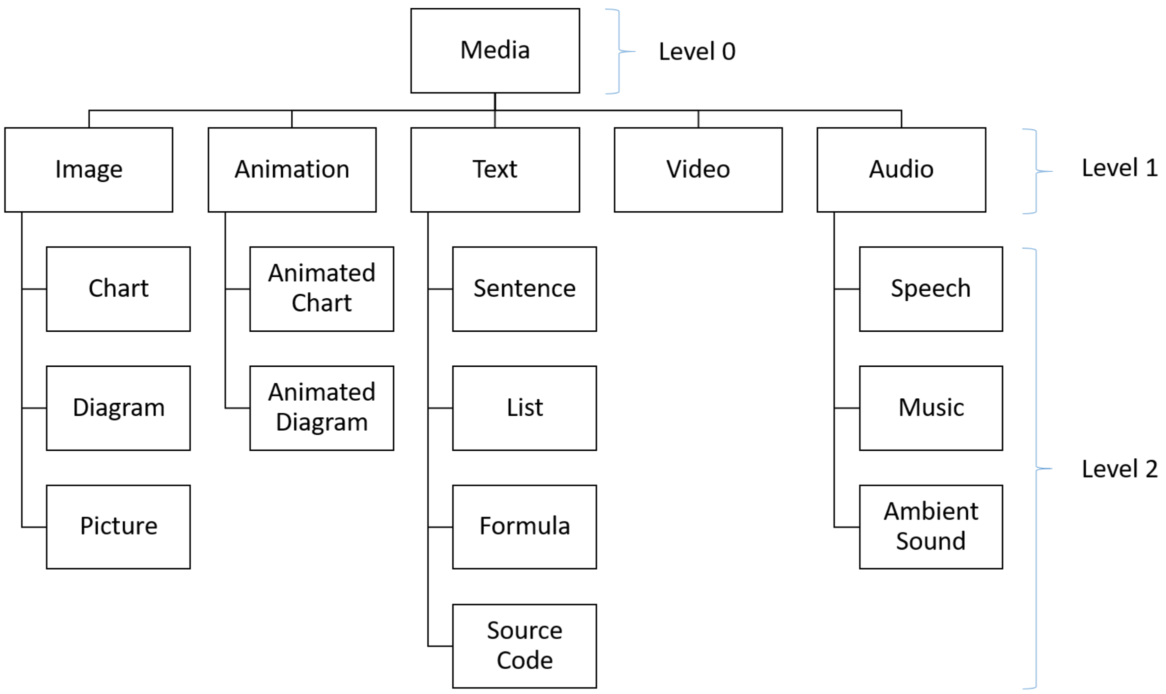


Figure 5.1: Hierarchical Media Taxonomy Diagram

From figure 5.1, we can see that Image is the parent of Chart and Media is an ancestor of Chart. Animated Diagram is a descendant of Media and a child of Animation. A brief definition of each of the media types and subtypes shown in figure 5.1, follows.

Image: This media type is visual in nature and is used to record visual perception about something, which may be a physical or abstract thing. Three subtypes of image, as described by this taxonomy, are listed as follows: -

- Chart: A chart is an image media type that is used to present a visual representation of data or anything that is data related. Examples are pie charts, histograms, line charts, scatterplots, etc.

- Diagram: These are images that are used to portray a visual model of something. This 'something' may be physical or concrete (such as a motor engine) or abstract (an idea or concept). Examples are maps, schematics, etc.

- Picture: A picture is a visual representation of something physical and tangible, usually created by capturing an image with a camera but not always. Examples are photographs, screenshots, etc.

Animation: Animations are, in simple terms, motion images. Images in general are still artefacts but animations usually introduce motion to images, sometimes created by displaying varying images successively, to create the illusion of motion. This taxonomy presents two subtypes of animation as follows: -

- Animated Chart: This is an animation which takes all the attributes of a chart and adds to it animation. For example, a chart may be animated to illustrate changes in variables with time. A good example of an animated chart is the motion chart.

- Animated Diagram: This is an animation which has all the attributes of a diagram, with motion added to it. For example, to illustrate the circulation of blood in the human body, a diagram of the heart and blood vessels could be animated. It is important to note that most animations are animated diagrams.

Text: Text is the most widely used media type available. It is, in simple terms, written words. There are some forms of use that make it necessary to create sub types of text.

- Sentence: This is essentially text that is used to convey information. For example, lots of sentences are used in any piece of writing, such as this.

- List: A list is a text type in which items are enumerated. It enhances the presentation of information about items that make up a set or group of something. An example could be a list of guidelines for enhancing software usability.

- Formula: This is a subtype of text which lends use in representing mathematical equations. An example (the volume of a sphere) is written as follows: - $V = 4/3 \pi r^3$

- Source Code: This is a text type that represents an instruction code such as a computer program. Although it is text, it is usually styled and indented to enhance readability.

Video: A video can be defined as a motion picture which may also involve the use of audio. While it may be a little like an animation, they differ in characteristics, in that videos usually contain real objects (but not always). Examples may be a video of a person demonstrating a physical exercise, or the video from a computer screen recording.

Audio: Audio is the media type which presents information that is processed by the auditory channel (or sense of hearing). It is essentially sound, anything we can hear. Let us consider some subtypes of audio, as defined by this taxonomy.

- Speech: Speech is essentially vocal communication or spoken words. We communicate daily using speech. Thoughts, feelings, and ideas are usually expressed using this media type and face-to-face information is usually presented in speech.

- Music: Music is essentially a harmonious audio or sound. Sometimes speech is used to create music, but the harmony involved gives it a distinct attribute.

- Ambient Sound: Given the huge variety and variability of audio, we have created this sub type of audio. In this taxonomy, ambient sound is regarded as the sound that is created from our environment. We live in a world full of sound, so it is essential that a category is created comprising the sound all around us. Examples are the sound of a dog barking, a vacuum cleaner, a car engine, thunder, etc.

It is expected that every media type (existing and new types) will fall into one of these categories. In rare cases, a media type may match the definition of more than one type. One example is an eye tracking heat map which (based on this taxonomy) can be classified as both a chart (the colour scheme is created from eye tracking data points) and a picture (it is essentially a screenshot). An example is shown in figure 5.2.

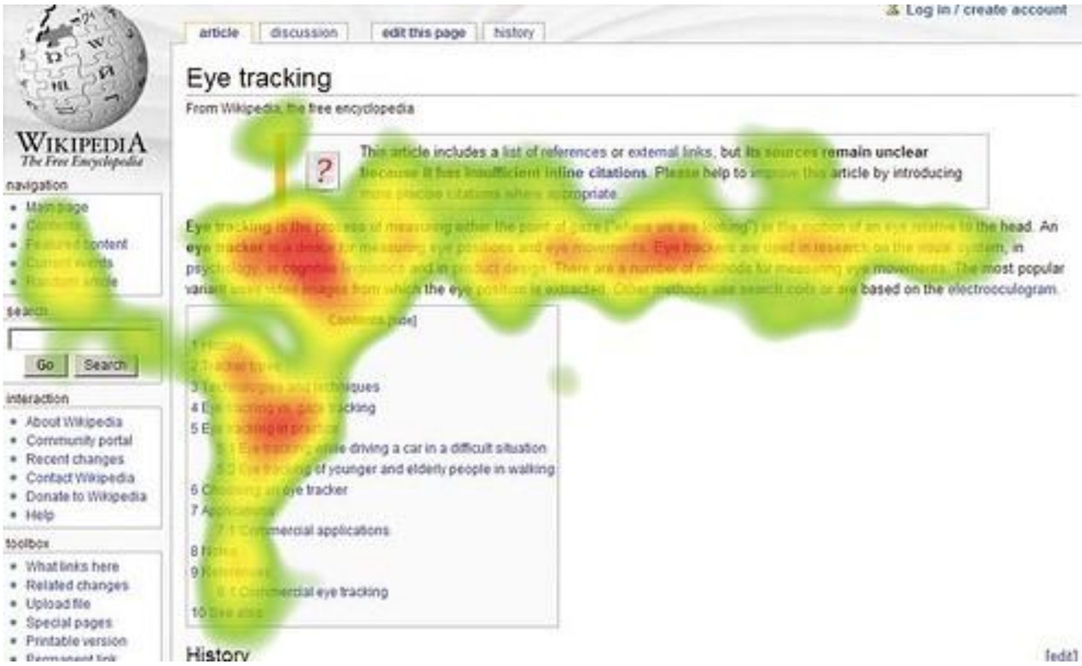


Figure 5.2: Eye-tracking heat map (source, http://tiny.cc/5nu3cz)

Another example is a thematic map for population density which can also be classified both as a chart (the colour shades are created from population density data) and a diagram (it is a geographic map which is a model of the landscape and any boundaries). See figure 5.3.

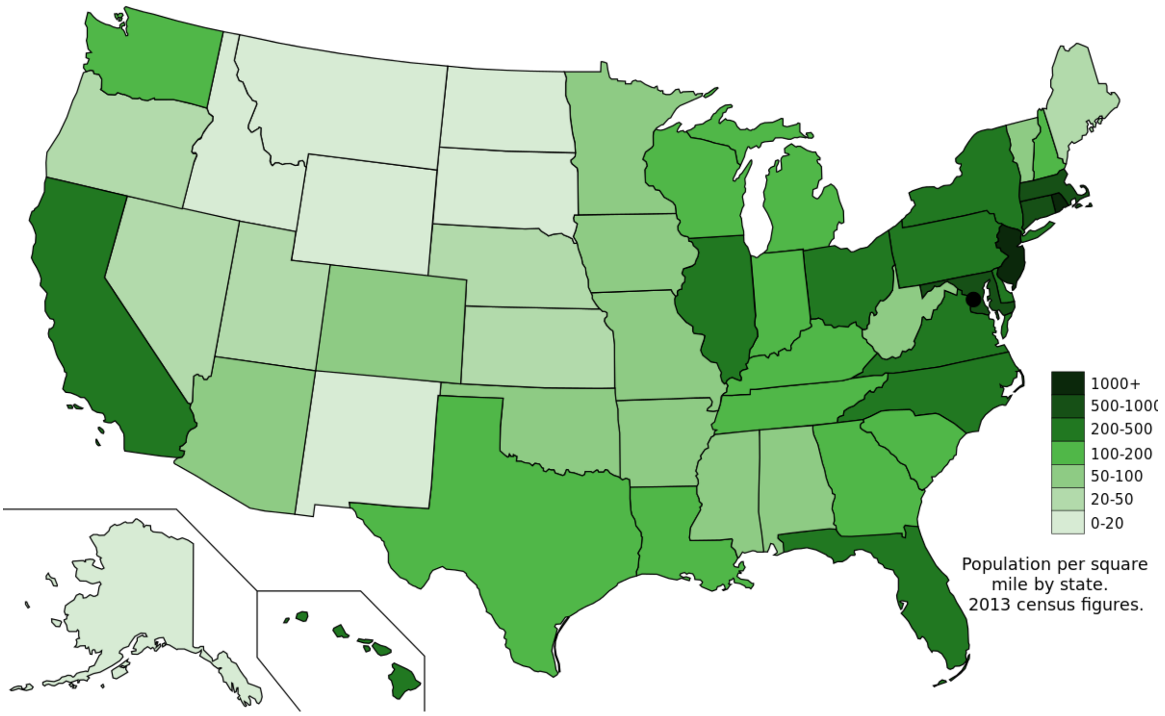


Figure 5.3: Thematic map for population density (source, http://tiny.cc/wuu3cz)

Where this happens, the user can place that media type as a sub type of any category that best matches what they intend to use it for. For example, the eye tracking heatmap (figure 5.3) is more likely to be used as a means for visualising data, rather than a screenshot, so it may be classified as a Chart. The thematic map for population density is also more likely to be used as a means for visualising population density, rather than a geographic map, so it may also be classified as a Chart. This media taxonomy provides a hierarchical approach to working with media types and lends help to the media selection method which is discussed in the next chapter.

5.4 Summary

It is known that relying on intuition and personal experience can potentially lead to the development of ineffective educational multimedia materials, therefore it is important that there is a methodical approach to media selection in the development of educational materials. In order to develop any media selection framework, one must have a good understanding of what media and multimedia are, and how many there are. This chapter outlines the definitions of media and multimedia that are used in this research. Of course, putting a number to all available media types is something that is very difficult, if not impossible to do, because new media types and variants of existing one are occasionally created. This chapter also presented a hierarchical media taxonomy which makes it possible to organise known media types in a hierarchical manner. The hierarchical media taxonomy uses inheritance-like relationships that are like the inheritance relationships in object-oriented programming. The media type at the top of the hierarchy is called Media and every media type is a sub type (or descendant) of Media. The sub types of Media are Image, Animation, Text, Video and Audio and these media types have an ‘is a’ relationship with Media. This chapter also outlines a simple heuristic for dealing with media types that fit into more than one category in this taxonomy. In the next chapter, a proposed method for selecting relevant media types during the development of educational material is discussed.

6 Media Selection: An Initial Design

6.1 Introduction

In the previous chapters, some multimedia design methods were reviewed and some of the issues with these methods were discussed. A study was also carried out to understand how educators design learning materials and findings from the study showed that most educators do not follow any multimedia design method but simply rely on intuition and personal experience. The problem with this is that relying on intuition and personal experience can lead to the selection of inappropriate media types for educational materials, which can also lead to the a less-than-optimal learning experience. In the preceding chapter, a hierarchical media taxonomy was discussed. This taxonomy makes it possible to organise any known media type in a hierarchical manner for use in the media selection method that is to be developed. The hierarchical media taxonomy begins with a media type called Media, with sub types of Media being Image, Animation, Text, Video and Audio, all of which have an 'is a' relationship with Media. This chapter discusses the development of an educational media selection method demonstrates how it can be used with a simple example.

6.2 Media selection and task analysis

The selection of appropriate media types for learning involves addressing one of the issues with multimedia design which is matching the media to the message (Sutcliffe, Kurniawan and Shin, 2006). When the media is matched correctly to the message, it enhances comprehension or understanding of the concepts being learned. To do this, it is important to understand what is required of the learning materials. What are the requirements? What are the learning goals? The educational material design process usually begins with determining these requirements and task analysis. Task analysis is used to fully establish what the communication goals are, the preconditions, the tasks and subtasks required for the learning process. This can be done in a variety of ways, but one way can be by adopting the Task Knowledge Structures approach (Johnson, Johnson, Waddington and Shouls, 1988) or Hierarchical Task Analysis (Annett, 2003; Stanton, 2006). Once the tasks and subtasks have been developed, details about communication goals for the educational material become known. The next stage will be to select the appropriate media types to represent the information intended for communication.

6.3 Information identifiers

Guidelines for the selection of media in the past have mainly provided advice without precisely identifying what media type to use in a given situation. In order to guide the process of media selection, a list of keywords that map to recommended media types were produced. These keywords are referred to as information identifiers (sometimes also referred to, simply, as identifiers). Every media type supports several structural elements (what may also be referred to as information presenting attributes) which form the basis for information expression and content organisation (Klenner, 2015). These elements or attributes underpinned the development of the information identifiers. The identifiers were produced by carefully examining the information presenting attributes or capabilities of several media types and using these attributes as a basis for the choice of the information identifiers. The information identifiers have meanings that are closely related to the information presenting attributes of their respective media types and this presents a simple way to think about the learning tasks to be accomplished, in consideration of the media types that are suitable for those tasks. The media types that map to these information identifiers are outlined in order of appropriateness. This means that when an information identifier is chosen, the first media type that it maps to is the most recommended media type.

The first step taken in the development of the information identifiers was to identify all the main media types available. Using the hierarchical media taxonomy presented in the previous chapter, the main media types are defined as Image (Chart, Picture, and Diagram), Animation (Animated Chart and Animated Diagram), Text (Sentence, List, Formula and Code), Audio (Speech, Music and Ambient Sound) and Video. The information presenting attributes of these media types make them uniquely suitable for conveying specific types of information or concepts. In order to identify what these are, one needs to carefully consider how information is presented with these media types and then determine what type of information would be best conveyed using each media type's modality. Different researchers have come up with different heuristics as a basis for media selection and some of these heuristics have been modified and used in part, as a basis for the development of these identifiers. Some of these heuristics include: -

- Static media should be used to convey detail (Faraday and Sutcliffe, 1998).
- Dynamic media should be used to engage users (Sutcliffe et. al., 2006).
- Maps and diagrams should be used to present spatial information (May and Barnard, 1995).
- A mixture of audio, video and synchronised text should be used to present complex procedural learning task (Bhowmick et. al., 2007).
- Charts and graphs should be used for quantitative information (Tufte, 1997).
- Diagrams should be used to illustrate abstract concepts, relationships, and models (Sutcliffe et. al. 2006).
- Videos or an array of images should be used to illustrate complex actions (Hegarty and Just, 1993; Sutcliffe et. al. 2006).

For each media type, a number of information identifiers that encapsulate the nature of the information or concepts that can be presented by that media type have been highlighted. The process for the development of the information identifiers for each media type is described as follows: -

(Static) Chart: Charts are a very useful media type under the image category, based on the media taxonomy. Charts are particularly very useful for presenting numeric data. Tufte (1997) recommended the use for charts for quantitative information. In consideration of the information that charts can be used to represent, *data* can be defined as an identifier for chart media types. This identifier was chosen because charts are very suitable for representing data and generally, quantitative information.

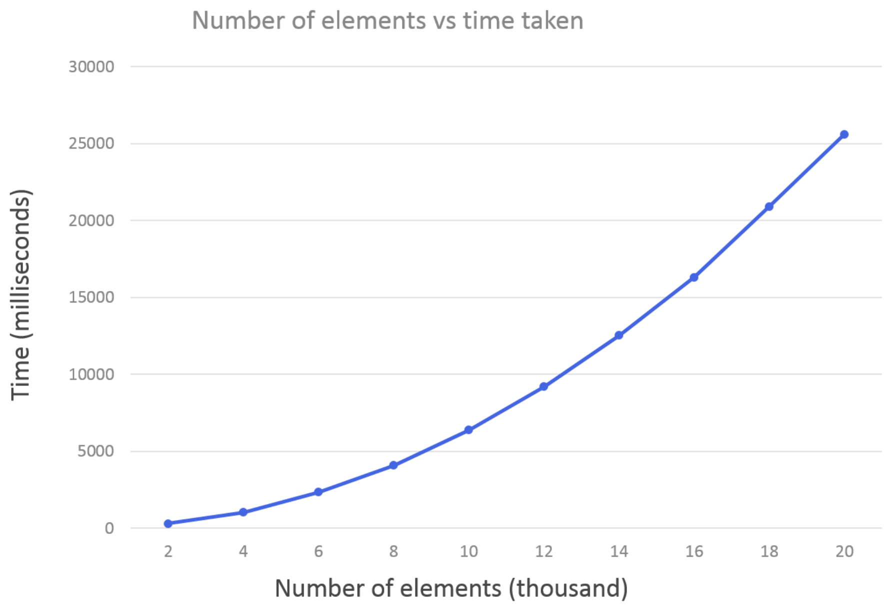


Figure 6.1: Sample chart

Picture: As described by the hierarchical media taxonomy, this media type is used to present realistic objects, in essence, as they are. In addition, a picture does not support motion or dynamic imagery, therefore they are suitable for concepts about physical objects that do not require the illustration of change, motion, or modelling. Three information identifiers for the picture media type were therefore defined. These are *object*, *static* and *reality*.

Figure 6.2: Sample picture (source, http://tiny.cc/ust2cz)

(Static) Diagram: Purchase (2014) defined a diagram as “a composite set of marks (visual elements) on a two-dimensional plane that, when taken together, represent a concept or object in the mind of the viewer”. Diagrams are particularly suitable for abstract representations or models. Sutcliffe et. al. (2006) suggested the use of diagrams for abstract concepts, relationships, and models. In some cases, the models that diagrams represent are of physical objects, for example, a diagram can be used to model parts of an engine or a lift pump. Finally, the attributes of a diagram can only allow the use of static representations. Therefore, the chosen information identifiers for static diagrams are *model*, *object* and *static*.

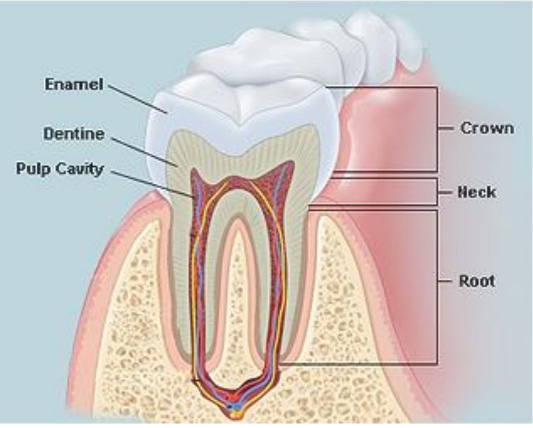


Figure 6.3: Sample diagram (source, http://tiny.cc/at93cz)

Animated Diagram: Animations are very useful in simulations and simulations have been shown to be effective in teaching science concepts (for example, Falloon, 2019). Animations, as a result of its attributes, are known to have the potential to facilitate the learning process (Schnotz and Rasch, 2008). For example, animations can reduce cognitive load by helping learners visualise a dynamic process, particularly when the learner is unable to mentally imagine that process (Salomon, 2012), in essence, they help in the construction of mental models (Rasch and Schnotz, 2009). Animations, in general, are suitable for dynamic events (Tversky, Morrison and Betrancourt, 2002; Betrancourt, 2017) and are very useful for depicting and pointing out the dynamic nature of processes such as mechanical and biological processes (Hegarty, 2005; Kriz and Hegarty, 2007). Animated diagrams are similar to diagrams except for the possibility to display dynamic content (which cannot be done with static diagrams). In line with Sutcliffe's guidelines (2006), animated diagrams should be used to represent abstract concepts and models, this time dynamically, which brings the possibility for it to be used for demonstrations, such as the lift pump described by Mayer (2003). The identifiers for animated diagrams are therefore *model*, *object*, *motion,* and *demonstration*.

Animated Chart: One difference between an animated chart and a static chart is the dynamic nature of the animation. Animated charts can show dynamic content (changing data), which is not possible with a static chart (referred to as a chart). In the case of an animated chart, the information identifiers are similar to a chart, except that an animated chart allows the possibility to present changing (dynamic) data in ways not possible with static charts. The dynamic nature of this type of chart makes it suitable for various kinds of demonstrations. The information identifiers for animated chart are therefore identified as *data, motion,* and *demonstration*.

Text: Text is the most basic and most widely used media type. The hierarchical media taxonomy described in the previous chapter presented four subtypes of text which are source-code, sentence, list, and formula. There is usually less focus on this media type by multimedia practitioners and images, animations audio and videos are generally thought of, in association with media and multimedia. Given the simplicity of these text types, one identifier for each of these types were created. They are *code* for source code, *requirements* for list, *maths* for formula, *message* for sentence.

Audio: Audio is generally regarded as one media type, however, in order to increase the specificity of media types recommended by this method, three categories or subtypes of audio were created. They are speech, music, and ambient sound as described by the hierarchical media taxonomy. Information from these media types is received through the verbal channel. Speech is generally used to deliver messages or information; therefore, the *message* information identifier was assigned to the speech media type. The kind of information that speech can be used to deliver, is similar to that of the text subtype, sentence. They therefore have the same information types. Ambient Sound and Music have been assigned to the general information identifier type, *sound*. Ambient Sound was also assigned to the information identifier, *reality*.

Video: Instructional videos refers to videos that are designed to help people learn (Fiorella and Mayer, 2018). Researchers generally agree that videos can be a very effective tool for education (for example, Allen and Smith, 2012; Kay, 2012; Lloyd and Robertson, 2012; Rackaway, 2012; Hsin and Cigas, 2013). One reason for this is that videos add auditory engagement to visual information, thereby allowing for more emphasis on the important aspects of learning, this time, using two channels (Stockwell, Stockwell, Cennamo and Jiang, 2015). Bhowmick et. al. (2007) suggested the use of videos for complex procedural tasks. Results from their experiments showed that videos (used in combination with audio) resulted in better learning outcomes for students. Al-Allaf and Khawatreh (2006) suggested that videos are more efficient (than audio lectures) for certain tasks such as teaching someone how to fix a part of an engine. Videos have attributes that make them a powerful information delivery media type, suitable for a wide range of applications. Videos are suitable for concepts that are more realistic in nature. In addition to realistic moving objects, videos would be suitable for concepts that require some sort of demonstration or tasks that require demonstration (for example, Brar and van der Meij, 2017; van der Meij and Dunkel, 2019). The identifiers for video media types were therefore defined *reality*, *motion*, *object,* and *demonstration*.

6.4 Description of the Information Identifiers

In the previous section, some information identifiers were proposed, and these were mapped to recommended media types. Given that the media selection process will begin with these identifiers, it is important that users understand what each information identifier represents, therefore, a brief explanation of each information identifier is outlined as follows: -

Code: This identifier should be used for concepts that involve programming. An example is when learning about computer programming and there is a need to show sections of a code for detailed explanation.

Data: This identifier should be used for concepts about numerical data or where there is a need to present data.

Maths: This identifier should be used for aspects of learning that involve mathematical statements or expressions. For example, when learning about the mean (average) in statistics, the maths identifier can be used because the mean can be expressed mathematically.

Model: Sometimes, learning concepts cannot be concisely presented without some sort of objectification and/or rescaling. Therefore, this identifier should be used for concepts that cannot be presented as is but require a different representation or need to be objectified to highlight important aspects. An example of when this could be used, is when learning about the atom.

Motion: This identifier should be used for concepts where the movement of objects is an integral part of the concept being learned. For example, when learning about planetary rotation, there is motion involved in the concept (the movement of planets) so the motion identifier could be used.

Object: This identifier should be used for concepts that are about physical items.

Reality: This identifier should be used when objects, events or phenomena need to be represented as they are. An example is when one needs to learn to identify a physical item.

Requirements: This identifier should be used for learning concepts that may need to highlight a set of rules or procedures about something. An example is when discussing ingredients for a recipe.

Sound: This identifier should be used for concepts where learning can only occur through the auditory channel. An example may be when learning about the sound of animals because such cannot easily be represented in text.

Message: This identifier should be used in cases that involve presenting descriptive or informational messages.

Static: This identifier should be used for concepts that do not involve the movement of things or objects. An example of when static may be used is when learning about different breeds of a dog.

Demonstration: This identifier should be used when an activity or process needs to be exhibited. For example, this identifier is used when there is a need to show how something works.

Table 6.1 shows the information identifiers and their recommended media types. The media recommendations are written in the order of recommendation. For example, in the table, the recommended media types for the data identifier are Chart and Animated Chart, however, Chart is the main recommendation for data, hence it appears first.

When using this media selection method, more than one of these identifiers can (and in most cases, should) be selected. Once the relevant information identifiers have been selected, the educational material developer then picks out the most occurring media type from the output list of recommended media types and calculates the ‘mode’ of the list of media types. This ‘mode’ media becomes the recommended media type. If there is a multimodal outcome (that is, where there are two or more media types with the same mode values), the educational material developer would need to look at the identifier-to-media mappings and retrieve the first appearing media type which is mapped to all the identifiers that were selected.

Table 6.1: Information identifiers and recommended media types

Identifier	**Recommended Media Type**
Code	Source Code
Data	Chart, Animated Chart
Maths	Formula
Model	Diagram, Animated Diagram
Motion	Animated Diagram, Video, Animated Chart
Object	Picture, Diagram, Video, Animated Diagram
Reality	Picture, Video, Ambient Sound
Requirements	List, Chart
Sound	Ambient Sound, Music
Message	Sentence, Speech
Static	Picture, Diagram
Demonstration	Video, Animated Diagram, Animated Chart

Any ‘mode’ media type which is also on this list then becomes the recommended media type. As mentioned earlier, the recommended media types have been listed in order of recommendation, but this order is only useful where there is a multimodal media type outcome.

6.5 Diagrams and Charts

In certain cases, there may not be sufficient information to recommend a specific media type from the identifiers that have been described. These include situations where the output media is a chart or a diagram (still or animated). In such situations, a second media selection may be required. Two sets of identifiers have been produced for these situations. One set is for charts (including animated charts) and the other is for diagrams (including animated diagrams). These identifiers have also been produced by carefully examining charts and diagram types, using their information presenting attributes or capabilities as a basis for the choice of identifiers.

6.5.1 Identifiers for Diagrams

In order to increase the ‘specificity’ of the media types recommended by this method, a number of commonly used media types under the diagram category were identified and sub-identifiers for these media types were developed. These media types include Flow Chart, Cycle Diagram, Timeline, Hierarchical Diagram, Concept Map, Mind map, Euler diagram, Venn Diagram, Schematic Diagram, UML Diagram, Heatmap, Thematic Map, Physical Map and Thematic Map. The same approach for the development of the main information identifiers was followed. The identifiers and a brief explanation of each is outlined as follows:

Process: This identifier may be used for concepts that involve the description of activities or tasks that occur in predefined steps or sequence.

Cycle: This identifier may be used for concepts that describe activities or tasks that occurs cyclically.

Algorithm: This identifier may be used for concepts that involve the description of steps required to complete a process.

Chronology: This identifier may be used for concepts that describe events and their time of occurrence.

Hierarchy: This identifier may be used for concepts that describe a hierarchical system of operation or organisation.

Relationship: This identifier may be used for concepts that need to highlight links between entities, or the concepts being described.

Concept: This identifier may be used when one needs to describe or structure ideas.

Object: This identifier may be used when details about an object (whether physical or abstract) needs to be presented.

Component: This identifier may be used when there is need to show the constituents of a system.

System: This identifier may be used when an organised method of operation needs to be described. This could be a physical (tangible) system or an abstract system.

Set: This identifier may be used when there is need to show group relationships for items or things.

Software: This identifier may be used when information about software needs to be described.

Data: Most diagrams do not depict data, but a few could show data in addition to the information model they display. This information identifier may be used when data needs to be depicted in a diagram.

Spatial: This information identifier may be used for concepts that have spatial attributes like position, area, and size.

Location: This information identifier may be used when locational information needs to be presented.

Table 6.2 shows each information identifiers and the recommended media types (diagrams). The media recommendations are written in the order of recommendation, that is, with the most recommended diagram appearing first on the list.

Table 6.2: Information identifiers and recommended media types for diagrams

Identifiers	**Recommended Diagrams**
process	Flow Chart, Cycle Diagram
cycle	Cycle Diagram
algorithm	Flow Chart
chronology	Timeline
hierarchy	Hierarchical Diagram
relationship	Hierarchical Diagram, Concept Map, Mindmap, Euler, Venn Diagram
concept	Concept Map, Mindmap
object	Schematic Diagram, UML Diagram
component	Schematic Diagram, UML Diagram
system	Schematic Diagram, UML Diagram
set	Euler Diagram, Venn Diagram
software	UML Diagram
data	Heatmap, Thematic Map
spatial	Physical Map, Thematic Map, Heatmap, Schematic Diagram
location	Physical Map, Thematic Map

The process for selecting media using these identifiers are similar to that of the main identifiers and also follow the same procedure for dealing with multimodal recommendations.

6.5.2 Identifiers for Charts

The identifiers and recommended charts are provided in table 6.3. The same process for the development of the main information identifiers was also followed.

Table 6.3: Information identifiers and recommended media types for charts

Identifiers	**Recommended Charts**
trend	Line Chart, Time Series Chart, Area Chart
record	Table
properties	Scatterplot, Table
comparison	Area Chart, Table
correlation	Scatterplot
relationship	Scatterplot, Table
discrete	Bar Chart, Pie Chart, Dot Plot
continuous	Histogram

A brief explanation of each identifier is outlined as follows: -

Trend: This identifier may be used when it is necessary to depict change of data over time.

Record: This identifier may be used when a record(s) of something needs to be shown.

Properties: This identifier may be used when there is a need to present information about entities that possess attributes.

Comparison: This identifier may be used when two or more data points need to be compared.

Correlation: This identifier may be used when there's need to visualise interrelationship between factors.

Relationship: This identifier may be used when connection between data needs to be examined.

Discrete: This identifier may be used for concepts that deal with distinct (or categorical) data.

Continuous: This identifier may be used for concepts that deal with data that has a range.

Again, these identifiers are used in much the same way as the main identifiers and follow the same procedure for dealing with multimodal recommendations.

6.6 The Media Selection Procedure

In the previous sections, a set of identifiers were developed using the information presenting attributes and capabilities of several media types and these were mapped to their recommended media types. In using these to select a media type in the development of educational material, one begins by first identifying all the tasks in detail. The next process is to select, for each identified task, a set of information identifiers from the main set of identifiers that are relevant to that task. Once done, the information identifiers are looked up on the recommendation table (table 6.1) and a list of all the recommended media types are written out. The mode is then calculated on this list and the mode media type becomes the recommended media type for that task. Should there be more than one mode (multimodal), the user must refer to the recommendation table and looks up the first recommended media type for each originally chosen identifier. Any of the multimodal media types that also appears on this 'list of firsts' becomes the recommended media type.

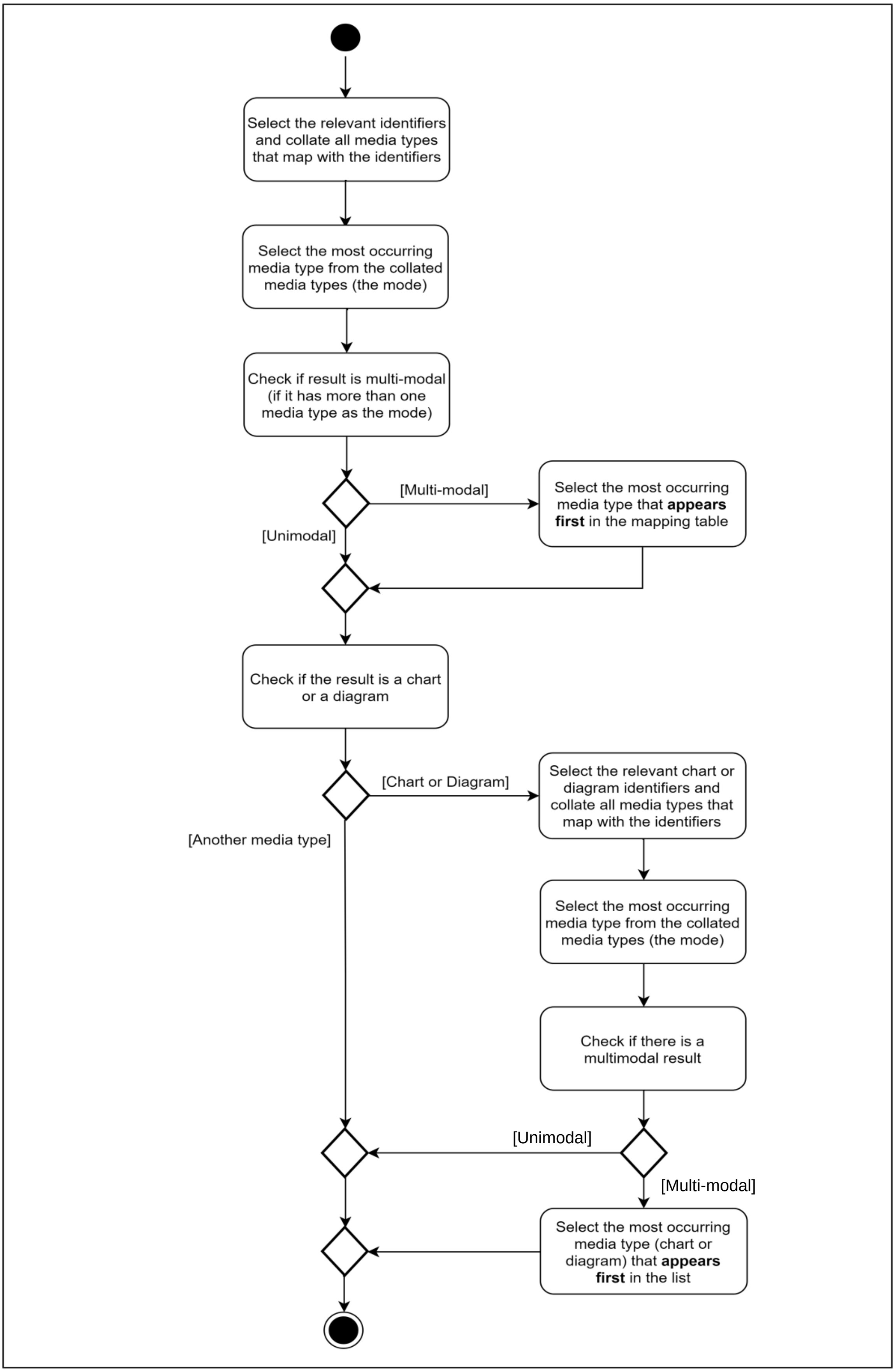


Figure 6.4: Flowchart outlining the media selection process

If this recommended media type is a chart or diagram, the process moves on to the chart or diagram media type selection respectively. In this case, there will be no need to identify new tasks. The user can simply look up relevant information identifiers in the chart or diagram mappings table, collate the list of recommended media types, calculate the mode on them which then becomes the recommended chart (or diagram). If there is a multimodal outcome, the process for dealing with multiple modes is applied. Figure 6.4 summarises the process in a flow chart.

6.6.1 Rationale for this procedure

The use of information identifiers (or similar) is not new in multimedia design methods, for example, they were used in Sutcliffe's multimedia user interface design method (Sutcliffe et. al., 2006). In the media selection method described in this chapter, identifiers provide a way to guide the user through the process of media identification as they based on the information presenting attributes or capabilities of the media types employed in the media selection method. As different media types have overlapping information presenting attributes, the use of identifiers will result in a number of media types being selected. To reduce it to one media type, we need to work out the mode (the most occurring media type) which becomes the selected media type for that particular concept.

6.7 Media selection tool

To ease the process of selecting media types using the method described in this chapter, a web-based tool was developed. This was developed as a stand-alone HTML and JavaScript application which means it can be launched by any browser, without requiring any web hosting. At launch of the program, it displays a screen which shows all the main information identifiers (see figure 6.5). Users can click on any information identifier to reveal its description. The tool utilises the same media selection logic that have been described. It allows users to select the relevant information identifiers for the identified learning tasks. The tool then processes the selected information identifiers and displays the recommended media type. If the recommended media type is a chart or a diagram, the tool would present the user with the relevant list of information identifiers (depending on whether it is a chart or a diagram) from which the user can select. It then processes these and displays the recommended media type. Screenshots of the tool are shown in figures 6.5 and 6.6.

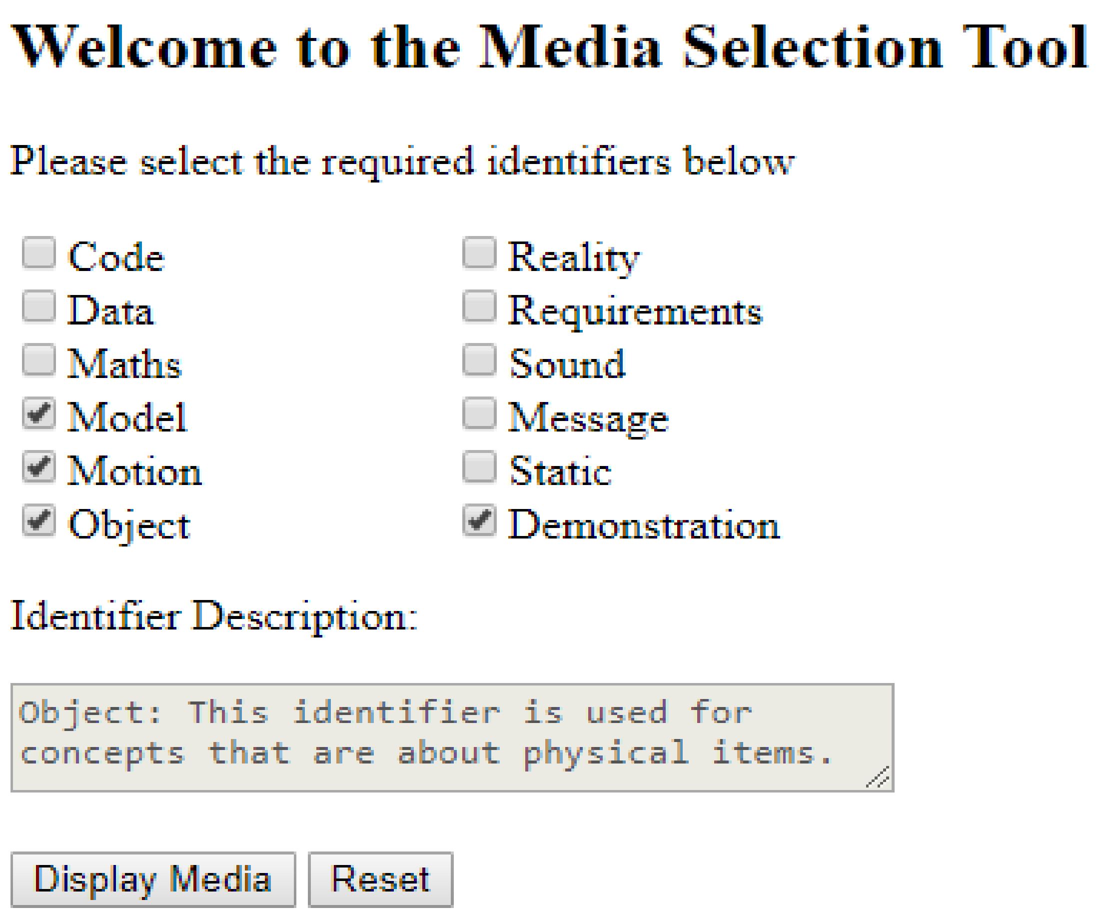


Figure 6.5: A screenshot of the media selection tool (main selection stage)

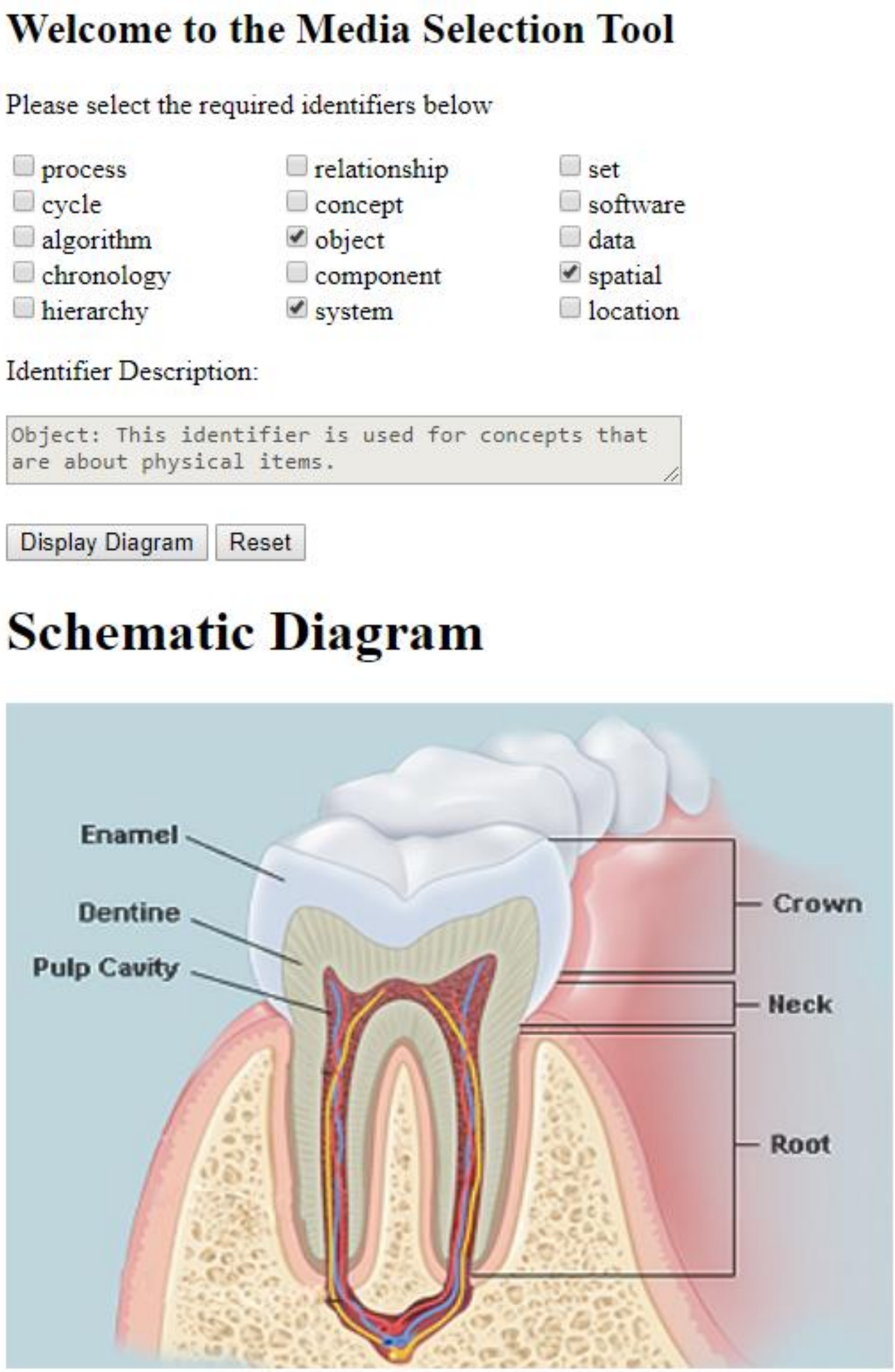


Figure 6.6: A screenshot of the media selection tool (diagram selection stage), with a sample of the recommended media type

6.8 Multimedia Material Development

This section demonstrates how this media selection method can be used using a practical example. This can be a very simple or complex process depending on educational concept but in this section, the process of developing a simple educational material about planetary revolution will be demonstrated. The first stage would usually be to do some task analysis, in order to identify all the tasks or activities that are required for learning process and the communication goals.

6.8.1 Setting out the learning tasks

The first stage is to set out the learning tasks and objectives. For this demonstration, the tasks/learning objectives would be kept as simple as possible. The following are the assumed tasks required for planetary revolution.

- Define planetary revolution.
- Demonstrate how planets revolve.

6.8.2 Selecting the identifiers and media

The first step involves examining the learning tasks and this is required in order to select the relevant identifiers. Let us now examine these learning tasks.

Define planetary revolution: This task is about the definition of planetary revolution. From the list of information identifiers, "message" would be selected. This is because a definition involves presenting informational messages. From the identifier-to-media mapping table (table 6.1), "sentence" and "speech" are the recommended media types. In this case, sentence would be selected because the recommended media types are multimodal (one sentence and one speech output), and sentence is the first occurring media type.

Demonstrate how planets revolve: This task is about the demonstration of an activity. Looking through the list of identifiers, the following identifiers would be selected:

- Demonstration: This would be selected because the task involves showing how planets revolve. This is an activity.
- Model: This would be selected because presenting this learning concept requires us to rescale the planets for presentation. It will require a model of a real planet.
- Motion: This would be selected because the learning concept intends to illustrate the movement (motion) of planets around the sun.
- Object: This was selected because the planets are physical objects.

When the recommended media types for these identifiers are collated, animated diagram is found to be the most occurring media type. This means that an animated diagram is required for the demonstration of planetary revolution. Although the suitability of an animated diagram for this educational material has now been identified, it is not known what type of diagram we need to animate, so we need to go through the second stage of media selection. Looking through the list of identifiers for diagrams (table 6.2), the following were chosen: -

- Object: This would be selected because, again, planets are physical objects.
- System: This would be selected because a mode of operation is being described.
- Spatial: This would be selected because the concept being described has spatial attributes (planets are in space).

When the recommended diagram types for these identifiers are collated, we find that schematic diagram is the most occurring diagram type. This means we need to use an animated schematic diagram to demonstrate the revolution of the planets. It is important to note that when the selection process yields an animated chart or an animated diagram from the first level selection, the user would have to go through the second-level selection, determine the media type (chart or diagram) required and then the user can add some animation to it. The user would be guided by the tool when this is required. This simple demonstration shows how educational materials can be developed using this method. It began by defining the tasks for the learning material development and then used the relevant information identifiers to select an appropriate media type to present the learning material.

6.9 Discussions

The positive effects of multimedia on learning have been highlighted in numerous studies as discussed in the literature review. Researchers have also highlighted the effects of different media types on learning (Bhowmick et. al., 2007; Sahasrabudhe and Kanungo, 2014) and work has been done to produce some guidelines for designing multimedia educational materials (e.g., Sutcliffe, Kurniawan and Shin, 2006). Media selection is a very important part of educational material design and is key to effective learning. It is evident from research that the use of inappropriate media types in educational material design can adversely affect learning (Bhowmick et. al., 2007; Chen and Sun, 2012) so the necessity to have a framework which educational material developers could use to select appropriate media types to present information cannot be overstated. In this chapter, a framework for media selection was introduced. The media selection framework sets out the process through which a user can identify a set of media types, use them to create information identifiers and map the information identifiers back to the media types. The framework relies on the multimedia taxonomy described in the previous chapter. This taxonomy provides the basis for a multimedia selection method which can be described as the current collection of media types, the information identifiers, the media mappings, and the way they are structured. A media selection method is created using the process defined by the media selection framework and is modifiable. While it is not possible to incorporate every existing media type into this framework, the hierarchical nature of the media taxonomy described in the previous chapter (which is being used by this framework) allows for the possibility of a more generic (or parent) media type to be used when a more specific media type is not available. For example, the media selection tool does not contain a media type for chemical structural diagrams normally used in the study of chemical compounds (which can be considered to be a more specific type of schematic diagrams), but a schematic diagram for learning tasks that involve the presentation of chemical formula will be recommended by the framework in such a case. As another example, the framework might recommend a UML diagram for the presentation of a software object, but it does not currently suggest what type of UML diagram to use. Guides or reference manuals could be used in such situations (e.g. Rumbaugh, Jacobson and Booch, 2004). The application of the hierarchical media taxonomy to the media selection method allows it to be extended when needed. This extension can be done by developing more information identifiers and mapping the identifiers to the relevant media types (or incorporating new media types). It is important to highlight that there is a trade-off between the specificity of the media types recommended by this framework, and its ease of use. It is also important to note that this framework is currently limited to the design of educational material for e-learning. The current specification of this framework means it is not suitable for other methods of delivering learning, such as printed books because media types like animations and speech cannot be ‘printed’. Work on this is presented in a future chapter.

6.10 Summary

In this chapter, a framework for the selection of media has been discussed and an example of how it could be used in the design of educational materials has been presented. The development of this framework began with the description of information identifiers which were produced by carefully examining the information presenting attributes or capabilities of several media types and using these attributes as a basis for the choice of the information identifiers. Next, the information identifiers were mapped to their recommended media types, beginning with the most recommended to the least recommended for each identifier.

Additional information identifiers were produced for charts and diagrams using the same process and the process for dealing with multimodal recommendations was also discussed. To make this framework easy to use, a web-based tool was developed. An example of how this framework may be used was a discussed. Of course, the framework is ineffective if it does not improve learning (which is the intended goal here). In the next chapter, experiments aimed at evaluating this media selection framework would be presented. The evaluation would seek to answer questions such as, does it improve learning, do educational material developers find it easy to use, can the framework be relied upon to produce consistent results.

7 Media Selection: An Initial Evaluation

7.1 Introduction

In the previous chapters, multimedia and learning were discussed and a number of multimedia design methods were reviewed. A study was also carried out to understand how educational multimedia materials are currently developed. The study revealed that intuition and personal experience are mostly relied on when developing educational multimedia. Subsequently, a hierarchical media taxonomy was developed, a method for educational media selection was proposed and an example of how the media selection framework could be used was presented. This chapter discusses two experiments aimed at an initial evaluation of the media selection framework that was developed. The aim of the first experiment is to test the validity of the media selection method that was developed. In essence, is there a statistically significant improvement in learning when learners learn from an educational material that was developed using the media selection method, compared to similar learning materials? The aim of the second experiment is to assess the usability and reliability of the media selection method. In essence, do users find the method easy to learn, useful and usable? Does it generate the correct media type intended by design, when used for the same information presentation task? The procedures followed in conducting these experiments are discussed in the next sections.

7.2 Validity Experiment and Research Hypotheses

The media selection method presented in the previous chapter is of no good if it does nothing to improve learning experience, retention, and transfer, therefore the validity experiment aims to answer a very important question. Does the media selection framework improve learning when used to design learning materials? From this question, we can formulate the hypotheses for this experiment.

- **Null hypotheses** (H_0): The use of the media selection framework does not improve learning when used to design learning materials.
- **Alternative hypothesis** (H_1): The use of the media selection framework improves learning when used to design learning materials.

To test for improvements in learning, two groups of learners would be presented with two sets of learning materials (one for each group). One would be a pre-existing learning material that is in current use for learning, obtained from a multimedia learning platform and the other would be a modified version of the pre-existing learning material. The modification of the pre-existing learning material would be done using the framework procedures. The participants would then be asked to undertake learning tests and the test scores from both experiments would be compared. Higher scores in learning tests for participants using the modified learning material (compared to the other participants using the pre-existing learning material) would be regarded as an indication of improved learning.

7.2.1 The Validity Experiment Design

An independent design was used for the validation experiment. There were two groups involved in this experiment, a control group, and an experimental group. The learning material used for this experiment was obtained from khanacademy.org and an unmodified version of the learning material was used for the control group. The media types used in the learning material were then modified, using the media selection framework, to produce a learning material which contained the same educational concepts but presented using media types (different media types where applicable) that were consistent with the framework guidelines. The modifications required in this case were not major as some of the media types used in the pre-existing (or unmodified) material were in compliance with the guidelines of the media selection framework. More precisely, there were five modifications to the pre-existing learning material. Four images were introduced (three diagrams and one picture) and one animated diagram was introduced.

7.2.2 The Learning Material

The learning materials used were obtained from the KhanAcademy learning website, khanacademy.org and consisted of different concepts in physics such as gravitational weight, centripetal and centrifugal forces, acceleration, energy, and work. To prevent modification of the learning material by the web authors during testing, the learning material was downloaded and served as a local HTML page on the test computer. The control group used the downloaded version of the learning materials. The same learning material was then modified, in accordance with the media recommendations of the media selection method that was developed, and this modified material was used for the experimental group. There were not many changes made to the pre-existing material as some of the media types used in it followed the guidelines of the media selection framework modifications. More precisely, four images (three diagrams, one picture), and one animated diagram were added to the experimental learning material. Care was taken not to alter the learning goals of the pre-existing learning material.

7.2.3 The Validity Test Participants

Participants were recruited and split into two different groups of roughly similar characteristics. There were sixteen participants per group, consisting of eight males and eight females. The participants were university students, mostly from the School of Computing in Staffordshire University. Eight males and eight females were chosen at random from the University’s libraries. They were students who came into the library to either study, meet or borrow books.

7.2.4 The Validity Test Procedure

On the test day, participants were welcomed and then asked to read and give their consent. Afterwards, participants were asked to complete a profile questionnaire. The data collected in this questionnaire was then used to assign participants to one of both groups, ensuring that the combined profiles for both groups were as similar as possible. Participants were then asked to study the learning materials for their assigned group. The learning activity was timed and had to be completed within twenty minutes and any participant exceeding that time would have to be stopped. The reason for timing the learning activity was to ensure that all subjects learned under the same conditions. Subsequently, the participants were asked to complete a multiple-choice test containing ten questions. The participant's performance in this multiple-choice test was used as an indication of learning retention and consequently, as a measure of how well the learning material helped their learning. The learning retention test had to be completed within ten minutes and participants would be stopped if they exceeded that time limit. Likewise, the reason for the timing was to ensure that all subjects were assessed under the same conditions, just as would apply in a real-world test.

7.3 Reliability and Usability Experiment

This part of the experiment was aimed at assessing the reliability of the media selection framework in recommending the media types intended by design. In essence, the experiment is designed to test whether the media selection framework would produce the same results under the same circumstances. The experiment also aims to assess the usability of the framework, that is, to answer questions such as whether the framework was easy to use, whether users found the framework easy to learn, whether they thought it was useful, etc.

7.3.1 The Design

Although it is possible to use the framework with only pen and paper, using it in such a way may prove difficult, so a web-based tool was developed to aid users of the framework in selecting media for educational materials (this tool is discussed the previous chapter). Participants in this part of the experiment would be required to use the web-based interface/tool that was developed, to simplify the media selection task. This web interface/tool would be made available to the participants, and they would be taught how to use it. After learning to use the framework and the web interface, participants would be asked to select appropriate media types for various educational concepts, using the web-based tool and afterwards, they would be asked questions about the perceived ease of use, ease of learning and perceived usefulness of the framework.

7.3.2 The Participants

Seven participants (three females and four males) were recruited for this experiment. The participants were known to the researcher through research work or research-related meetups and had agreed to participate in the experiment. All participants had at least one year of experience in teaching and/or designing learning materials, with the most having six years of teaching and educational multimedia design experience. The mean experience in years was 2.57. These participants were considered representative given that they had been involved in teaching and/or the design of learning materials at some point in the past.

7.3.3 The Procedure

Participants were first asked for their consent to participate in the experiment. Once consent was obtained, participants were asked to complete a profile questionnaire. This was done to ensure that every participant meets the minimum criteria for participation which are that they must have been involved in either teaching or designing learning materials in the past and they must have at least one-year experience in the same. A PowerPoint slideshow was used to train the participants to use the media selection framework. Participants were also taught how to use the web-based tool for the media selection task. After training the participants to use the media selection tool, they were presented with ten educational concepts and were asked to use the media selection web tool to identify and prepare suitable media types for the educational concepts. At the end of the media selection task, participants were asked to complete a scaled-down version of Lund's USE questionnaire (Lund, 2001) aimed at assessing the perceived ease of use and usability of the tool and the framework. Finally, a NASA TLX workload assessment (Hart, 2006) was done to measure the workload of the media selection task.

7.4 Results and Discussion

The experiments conducted in this research sought to answer some important questions about the media selection framework developed such as whether using the framework to prepare educational multimedia will have a positive effect on learning, whether educational multimedia developers will find it easy to learn and/or use the framework and whether it produces the same media selection output when used for the same educational concepts. These results of the experiment are discussed in the next few sections.

7.5 Validity Test Results

An independent samples t-test statistic was used to analyse the results of the validity experiment, that is, the multiple-choice learning test scores. The retention test scores of the control group were compared with the retention test scores of the experimental group. At first, the data were checked for normality using Shapiro-Wilk’s test and the data from both groups satisfied the assumption of normality. Figures 7.1 and 7.2 show a normal Q-Q plot of the test scores for participants in the control group and the experimental group.

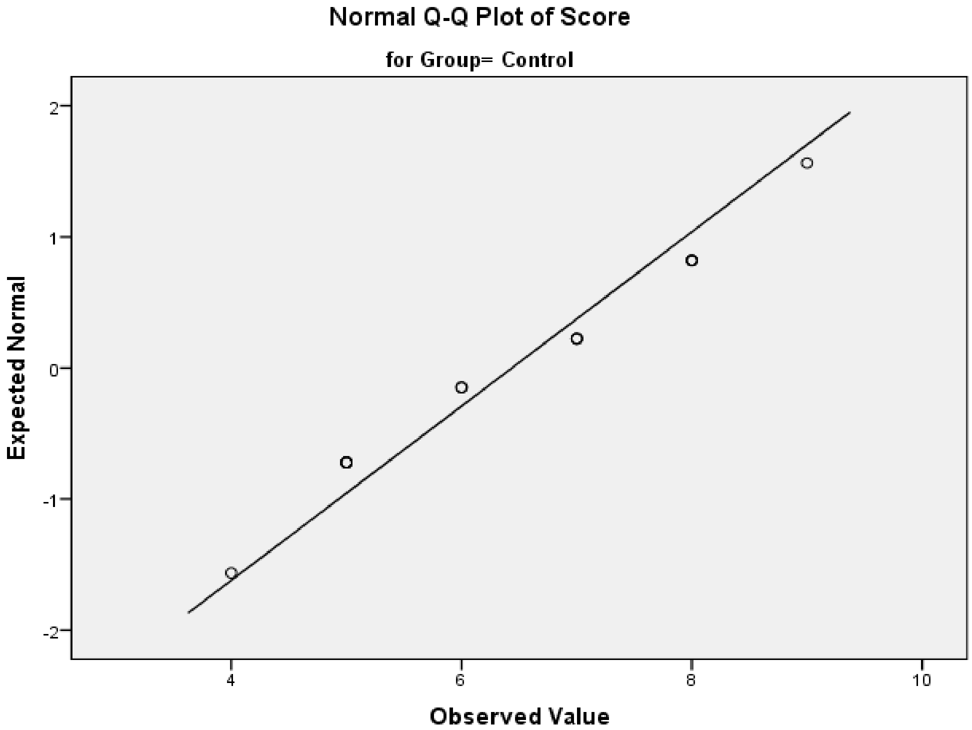


Figure 7.1: Normality Plot - Control Group

Participants in the control group obtained a mean test score of 6.44 (*SD* = 1.504). In comparison, participants in the experimental group obtained a numerically larger mean test score of 7.56 (*SD* = 1.459). To test whether the learning retention test scores of the experimental group was statistically significantly higher than the control group, an independent samples *t*-test was done. The assumption of homogeneity of variances was tested and satisfied via Levene's test, $F\ (30) = 0.238$, $p = 0.629$. The results of the independent samples t-test showed that the higher mean score of the experimental group, compared to the control group, was statistically significant, $t\ (30) = 2.147$, $p = 0.04$. Cohen's *d* was estimated at 0.76, which is a moderate effect size, based on Cohen's (1992) guidelines (Cohen's guidelines suggests that a *d* value of 0.2 should be considered a small effect size, 0.5 a medium effect size, and 0.8 a large effect size). This means that we can reject the null hypothesis that the use of the media selection framework does not improve learning and accept the alternative hypothesis which states that the use of the media selection framework improves learning when used to design learning materials.

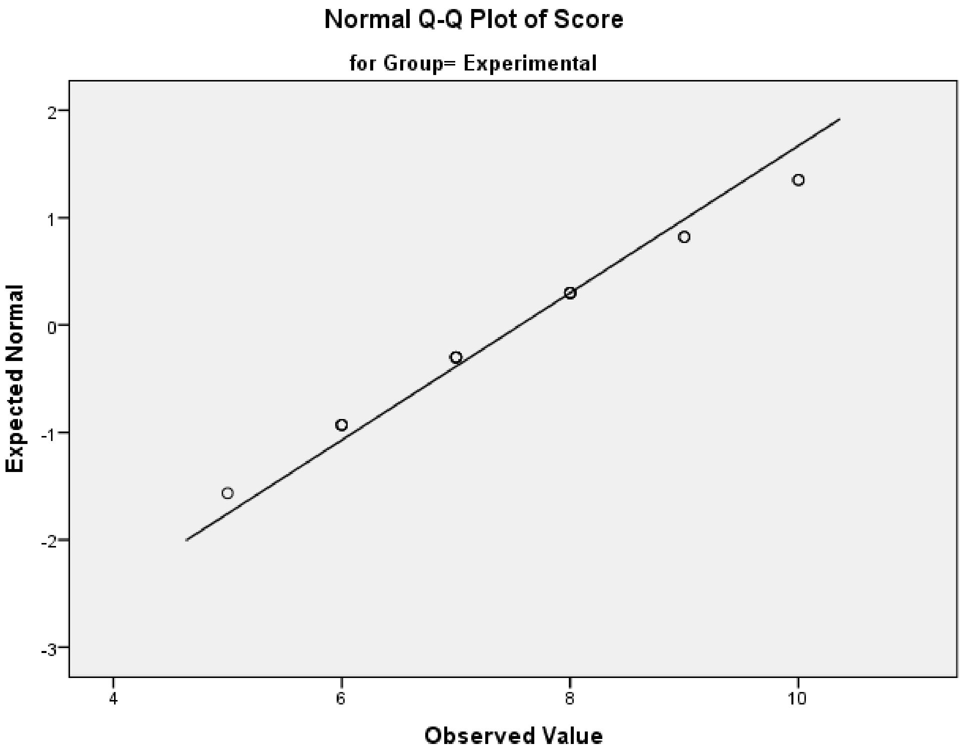


Figure 7.2: Normality Plot - Experimental Group

7.6 Reliability and Usability test results

In the media selection task for the reliability test, participants were presented with ten learning tasks and were asked to use the media selection web tool to identify and prepare suitable media types for the educational concepts. A media selection by the participant that corresponded with the recommended media type from the media selection framework, was regarded as a successful selection of media and attracted a score of 1, while a mismatch was regarded as an unsuccessful selection of media and attracted no score. The sum of the media selection scores of the seven participants ranged between 4 and 9 (out of a maximum of 10) (M = 5.43, SD = 1.90). The overall workload score of the subjective workload assessment of the media selection task (the NASA TLX) ranged from 32 to 66 with an average of 50.

The usability questionnaire made use of a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Table 7.1 shows the frequency distribution (in percentage) of the USE questionnaire data. The positive column represents ratings from 5 - 7 (those that tended to agree, agreed, or strongly agreed with the statement), the neutral column represents ratings for 4 (those with a neutral opinion about the statement), while the negative column represents ratings for 1 - 3 (those that tended to disagree, disagreed, or strongly disagreed with the statement).

7.7 Discussion

Multimedia is known to hold huge potentials for learners. The promise of multimedia is that people learn and retain information better when the right multimedia is used in learning and the results of this study have further confirmed this. However, in the absence of a methodical approach for selecting media specifically for educational materials, educational material developers may rely on intuition and personal experience, which might have a negative effect on learning. To solve this problem, a method for educational media selection was developed and embedded into a simple-to-use web tool and validity tests were carried out to validate the method. The results of the validity experiment have shown that the developed method has a real potential to improve learning when correctly used.

Table 7.1: Frequency distribution of the USE questionnaire data

	POSITIVE	NEUTRAL	NEGATIVE
USEFULNESS			
It helps me be more effective	71.43%	14.29%	14.29%
It helps me to be more productive	71.43%	14.29%	14.29%
It is useful	85.71%	0.00%	14.29%
EASE OF USE			
It is easy to use	57.14%	14.29%	28.57%
It is user friendly	57.14%	14.29%	28.57%
Using it is effortless	42.86%	42.86%	14.29%
EASE OF LEARNING			
I learned to use it quickly	57.14%	0.00%	42.86%
I easily remember how to use it	71.43%	14.29%	14.29%
It is easy to learn to use	57.14%	14.29%	28.57%
SATISFACTION			
I am satisfied with it	57.14%	14.29%	28.57%
I would recommend it to a friend	71.43%	0.00%	28.57%
I feel I need to have it	57.14%	14.29%	28.57%

Statistically significant differences were observed between those who learned using educational material developed using this method and those who learned using the non-method-based learning material. While the results of the validity experiment showed that using the method did improve learning, the results of the usability assessment showed that more work may be required to make it easier for users to learn to use the method because the consequence of users not fully understanding how to use the method is that incorrect media types may be inadvertently used for educational material design, thereby negatively affecting learning. From table 7.1, it can be seen that participants thought the method helped them become more effective (71.43%), more productive (71.43%) and participants considered the method useful (85.71%). However, moving on to its ease of use and ease of learning, the data shows a drop in positive feedback received. The reduced ease of learning was also evident in the test results as participants were, on average, only able to correctly answer just over 5 of the media selection tasks (the average score was 5.43 out of 10). One of the feedbacks received during the second experiment was that it would be very helpful to expand the descriptions of the information identifiers. Another participant also suggested adding more examples, covering different scenarios when each identifier may be selected. Another feedback received was concerning the number of output media types. The participant suggested that the media output could be grouped into two sections where one section would display the recommended media type and the other would display alternative media types that could also be used (even if it may not be as effective as the recommended media type). The reason given for this suggestion was that some media types are more expensive to create than others (expensive here refers to either the time it may take to create it or the cost of purchasing software tools and/or people to create the media type or both). This could prove useful in situations where an educational material developer may not be able to deploy the recommended media due to time or financial constraints. More work needs to be done to improve the ease of learning of the method and also to incorporate some of these recommendations to the method. The next section discusses the needed changes.

7.8 The need for improvements

The positive effects of multimedia on learning have been highlighted in numerous studies (for example, Mayer, 2003; Mayer 2009). Researchers have also highlighted the effects of different media types on learning (Bhowmick et. al., 2007; Sahasrabudhe and Kanungo,

2014) and some work has been done to produce guidelines for designing multimedia educational materials (e.g., Sutcliffe, Kurniawan and Shin, 2006). In earlier chapters, a hierarchical media taxonomy which described a way to classify available media types (both existing and new types) was outlined. A framework for the selection of media was also proposed and a demonstration of how it could be used in the design of educational materials, suitable for e-learning systems, was done. This chapter presented an initial evaluation of the media selection method that was developed. The results of the experiments conducted, showed that although learners performed better at learning retention tests when the framework was employed, participants who used the framework for media selection did not find it very easy to learn. One explanation for this is that users needed to fully understand the meaning of each of the information identifiers before they could effectively use the framework. Although gaining a full understanding of this may take some time, the belief is that it can get easier with practice. The experiments conducted in this chapter have helped to shed some light on some of the work that needs to be done to further improve the framework, particularly the ease to which it can be learned and used. In the next sub sections, the work that needs to be done is highlighted.

7.8.1 Improvements to the information identifiers

The media selection framework makes use of keywords (also referred to as information identifiers) therefore it is important that users of this media selection method fully understand what each information identifier (or keyword) means. Findings from the experiment showed that the definition and description of every identifier need to be improved. More examples of when each information identifier should be used, need to be provided. Work therefore needs to be done to improve the information identifiers.

7.8.2 Suggestion of alternative media types

The media selection framework currently outputs or recommends only one recommended media type. During the usability and reliability experiments, one of the participants suggested that while it is good to have one main media recommendation, it may also be useful to have one or two more alternative media type recommendations. This suggestion was given because there may be situations where an educational material developer may not have the resources (time or finance) to develop learning materials using the recommended media type. In such cases, the developer may want to know what other media type(s) they could consider using. This makes the introduction of alternative media type(s) a useful add-on to the framework because it gives the user more choice.

7.8.3 Support for learning models

In the literature review chapter, some learning models were reviewed one of which was the VARK learning model. The VARK model utilises sensory modalities to group individuals into categories that represent how they best learn. These four modalities are Visual, Auditory, Read/Write and Kinaesthetic. The visual preference uses media types like maps, images, diagrams, and charts to depict information that could have otherwise been written in text form. Visual learners tend to prefer to learn using media types such as charts and diagrams. Auditory learners prefer to learn from spoken words or using communication means that is “heard” such as speeches, discussions, and lectures. Read/Write learners learn best by reading text while kinaesthetic learners prefer to learn by doing exercises or practicing the concepts being learned, and therefore, prefer to learn using videos, demonstrations, and simulations. The media selection framework that has been developed does not have support for different learning styles/models therefore support for a learning model needs to be built into the framework. A closer look at this learning model shows that there is some relationship between the sensory modalities and preferred media types. For example, visual learners prefer charts and diagrams, auditory learners prefer speeches, etc. Therefore, this media selection framework can be modified to support the VARK learning model so that educational material can be tailored to a learner's preference. Doing this also presents an opportunity to contribute to the debate around the effect of learning styles on learning by comparing the effectiveness of learning when the educational material is tailored to the learner's style, to when it is not tailored to a learner's preference but only focuses on using the most effective multimedia material. As some researchers have questioned the effectiveness of learning styles, the outcome of this comparison may provide yet more evidence for or against the effectiveness of learning styles or preferences.

7.8.4 Support for media type retrofitting

New media types are being created occasionally, although many never become mainstream. As time moves on, new media types or sub-types may make this media selection method obsolete. It is therefore important to develop the media selection framework in such a way that it is extensible and can support future media types. With such a feature, an educational material developer can still use the framework to work with new media types when they are created.

7.8.5 Targeting specific "devices"

Although multimedia content is usually created for use on computers, multimedia can still be used in limited form on other "devices" like books. This limited form means that some media types cannot be used on some devices. For example, Klenner (2015) stated that "it is impossible to use a video or audio clip on a simple sheet of paper". A useful extension to this framework is the ability to target the media selection to a specific device, such as a book or a computer, so that the recommended media would be appropriate for the device on which it will be used.

7.9 Summary

We know from the literature review that the type of media used in presenting educational information is crucial to learning performance. Equally as important, is the way in which the multimedia material is designed for use. The previous chapter introduced a method for media selection in the design of educational material. This chapter discussed a few experiments aimed at validating the media selection method. These are the validity experiment (assesses whether the media selection method improves learning), the reliability experiment (assesses whether the media recommendations are the ones intended by design and that the method returns consistent results in the same context), and the usability experiment (assesses how usable the method and web-based tool are). Findings from the experiments have shown that although there were improvements in learning, some changes need to be made to the media selection framework. These changes include improvements to the description of the information identifiers (so as to enable users better and more quickly understand what they mean), support for alternative media type suggestions (which could be used in situations where the recommended types could not be used), support for adapting a selection to a learner's preference, the possibility to retrofit the method with new media types (so that the supporting application is not made obsolete by the introduction of new media types or sub-types) and the possibility to target the selection process to a device (so that the framework can still be used in situations where some media types cannot be used on some devices). The next chapter discusses these changes and the design of a new media selection tool with these functionalities built in.

8 Media Selection: Improvements

8.1 Introduction

In chapter six, a method for the selection of media types used for educational materials was developed and keywords (also known as information identifiers) for this method were produced. These identifiers were produced by carefully examining the information presenting attributes or capabilities of the media types obtained from the hierarchical media taxonomy and using these attributes as a basis for the choice of the identifiers. Identifiers were also produced for charts and diagrams as these media types also have sub types, thereby making it necessary that the media selection process is also performed down into the sub-type level, in order to achieve a more specific media output. In chapter seven, experiments were conducted to assess the effectiveness of this selection method. In essence, the experiments set out to investigate whether the media types identified by this method led to effective learning experiences, whether they were consistently producing the same media type when used in the same context and for the same concepts, and whether the method was reasonably usable by practitioners. The validity test results showed a statistically significant improvement in learning (measured by test scores) when the framework was used, compared to when it was not. However, during the reliability and usability tests, several areas for improvements were identified. These include improvements to the description of the information identifiers, suggestion of alternative media types, support for learning models, the ability to retrofit the framework with new media types and the ability to tailor the media selection process to specific ‘devices’ (by device, we mean the medium through which the educational material is delivered, for example, books, computers, etc). This chapter discusses the improvements that were made to the media selection framework. It also discusses the design and development of a new system which provides support for the changes that were made.

8.2 Improving the Information Identifiers

The media selection framework makes use of keywords (also referred to as information identifiers) which are the starting point of the media selection process. Being able to use this media selection process correctly, depends on the user's understanding of these information identifiers. Therefore, it is important that users of this media selection method fully understand what each information identifier (or keyword) means. Findings from the reliability and usability experiment in chapter seven showed that the definition and description of each identifier needs to be improved. Good examples of when each information identifier can/should be used, need to be provided. As a result, the description of the information identifiers had to be enhanced. In addition to this, at least one clear example of when each identifier may be selected was also provided as part of the description. This modification had the following format.

Description:	A brief description of this information identifier.
Example(s) & Rationale:	One or more examples of when this information identifier may be selected and the reason for selecting the information identifier for the outlined example.

In addition to the outlined format, a recommended word range was also proposed. This is because if the description contains too many words, users will spend more time reading the description. This would increase the time and effort it takes to use the media selection method, thereby increasing the possibility of users finding the framework too difficult to use and then abandoning it, or reading through the descriptions very quickly, misunderstanding them and then selecting inappropriate identifiers. The proposal is that for each information identifier, the description, one example and the rationale should contain between 50 and 150 words. There can be two or more examples (which may take the word limit beyond 150), but it should be up to the user to decide if they want to look at more examples. Given that the average person reads about 228 words per minute (Trauzettel-Klosinski, Dietz, and IReST

Study Group, 2012), this word range was proposed so that it takes the average person well under a minute (around 13 – 39 seconds) to read the descriptions for each information identifier. The new descriptions for each information identifier are provided in the next section.

8.2.1 Descriptions for the main information identifiers

This section outlines the updated descriptions of the information identifiers for the main media types, using the format discussed in the previous section. The mappings of each information identifier can be found in table 6.1.

Code: This identifier may be selected in situations where the aim is to teach programming or programming-like concepts. In many cases, it is not just enough to just explain how a program or function can be written, or its syntactic rules, without showing an example of such.
Example & Rationale: A user may select the code identifier when teaching about functions or methods in a computer programming subject. This is because such a subject involves writing computer source code which would be best portrayed by the source code media type as it provides colour schemes and indentation suitable for this kind of subject.

Data: This identifier may be selected where the aim is to teach a concept for which numerical data is an integral part of, that is, where there is a need to present data visually.
Example & Rationale: A user may select this identifier when teaching about the effect of an increase in input size on the running time of a logarithmic or quadratic algorithm. This is because this involves data which need to be visualised to enhance conception of the topic.

Maths: This identifier may be select when teaching about concepts that involve (or can be reduced to) mathematical statements or expressions.
Example & Rationale: A user may select this identifier when the subject is about the mean

(average) in statistics. This is because the statistical mean can be expressed using mathematical formulae. This can make it easier to remember and more concise.

Model: Sometimes, learning concepts cannot be concisely presented without some sort of objectification and/or rescaling, therefore this identifier may be selected in situations where the concepts being taught cannot be presented as they are but require a representation or need to be objectified to highlight important aspects.
Example & Rationale: An example of when this identifier may be selected, is when learning about the atom. The atom cannot be seen with the naked eye and therefore will need to be modelled and rescaled to highlight important aspects of it, such as the protons, neutrons, the nucleus and the elections. Another example might be when trying to depict an idea or a thought.

Motion: This identifier may be selected for the teaching of concepts where some sort of movement or activity (usually of objects) is an integral part of the concept being learned.
Example & Rationale: An example of when this identifier may be selected, is when learning about planetary rotation. This is because there is motion involved in the concept (the movement of planets) so the motion identifier could be used.

Object: This identifier may be selected in situations where the concepts being taught are about physical or tangible items.
Example & Rationale: An example of when this identifier may be used, is when learning about computer hardware. Computer hardware are physical items and therefore can be referred to as tangible objects. This identifier could be selected when teaching people to be able to identify computer hardware.

Reality: This identifier may be selected in situations where objects (usually), events or phenomena need to be presented as they are. In order words, where altering the real nature of an object will affect the goal of that learning task.

Example & Rationale: An example of when this identifier may be used is when one needs to learn to identify a physical item, such as a computer item as earlier described. This is because for one to be able to identify physical objects, such a person requires to a great extent, the experience that comes with seeing the object in its real form.

Requirements: This identifier may be selected where the teaching involves concepts where there is a need to highlight a set of rules or procedures about something or how to do something.
Example & Rationale: An example of when identifier may be used is when teaching about how to prepare a chemical compound or how to prepare a meal (recipe). This is because, usually in these situations, there are actions to be performed in an ordered fashion.

Sound: This identifier may be used for concepts where learning can only occur through the auditory channel or when information can only be received through the auditory channel.
Example & Rationale: An example of when this identifier may be selected is when learning about the sound of animals or different phenomena. This is because sound cannot easily be represented in text and therefore requires that it is heard for anyone to adequately learn to identify such or understand the underlying information. The sound (sonic boom) that a supersonic aircraft creates has to be heard to be appreciated or understood.

Message: This identifier may be selected for teaching concepts that involve presenting descriptive, informational messages, or explaining concepts.
Example & Rationale: An example of when this identifier may be selected is when writing a story or defining a concept (or words) using text or speech, just as in dictionary word definitions. This is because words are required to present these kinds of information, either using sentences or speech.

Static: This identifier may be selected when teaching about concepts that do not involve the movement of things or objects. This identifier has a mutual exclusivity with the motion identifier. This means that both should not be used together during an instance of the media selection process.

Example & Rationale: An example of when this identifier may be used is when learning to identify colours. This is because there is nothing about learning to identify colours that requires any sort of motion or change.

Demonstration: This identifier may be selected when learning concepts involve an activity or process that needs to be exhibited or *demonstrated*. This is usually the case when there is a need for an individual to physical show how something is done or how something works.

Example & Rationale: An example of when this identifier may be used is when there is a need to teach about to weld a metal. Demonstrating the process to learners makes it much easier to learn than when such is described through other non-demonstrated means.

8.2.2 Descriptions for diagram and chart information identifiers

The next two sections outline the updated descriptions of the diagram (section 8.2.3) and chart (section 8.2.4) information identifiers using the format discussed in the previous section. The mappings for each information identifier can be found in table 6.2 for the diagram identifiers and table 6.3 for the chart identifiers.

8.2.3 Descriptions for the Diagram Identifiers

The updated descriptions for the diagram information identifiers are outlined as follows: -

Process: This identifier may be selected when teaching about concepts that involve the description of activities or tasks that occur in predefined steps or in sequence.

Example & Rationale: This identifier may be selected when teaching about the process for troubleshooting a malfunctioning engine. This is because there are usually steps that a technician must follow in order to determine the cause of a malfunction in an engine. Using a flowchart to present the actions and decisions required for such an activity makes it easier to follow.

Cycle: This identifier may be selected when teaching about concepts that describe activities or tasks that sequential but repetitive in the sense that the flow in the sequence wraps round to the first task or action after the last action is complete.
Example & Rationale: An example of when this identifier may be selected is when teaching about the biological life cycle or the systems development life cycle. This is because the activities involved are sequentially repetitive. In the case of the systems development life cycle (one of several models), activities begin at the planning stage, then analysis, then design, then implementation, then maintenance and then it wraps back to the planning stage for any new functionality or extension of the system.

Algorithm: This identifier may be selected when teaching about concepts that involve the description of steps (and any associated decision) required to complete a task or solve a problem. This identifier is similar to the process identifier earlier described but may be more appropriate for computing-related concepts.
Example & Rationale: An example of when this identifier may be selected is when teaching about a binary search algorithm. The binary search algorithm involves performing a set of tasks in a specific order and making decisions.

Chronology: This identifier may be selected when teaching about concepts that describe events or milestones and their time of occurrence. These will usually be historic events but may also be future events or milestones that have yet to be achieved provided there is a defined time at which the event or milestone is expected to occur.
Example & Rationale: An example of when this identifier may be used is when teaching about events that took place during World War 2.

Hierarchy: This identifier may be selected when teaching about concepts that describe a (or have an inherent) hierarchical system of operation or organisation.
Example & Rationale: An example of when this identifier may be selected is when teaching specifically about the inheritance relationship between specific classes in a programming library of classes. This is because classes in object-oriented programming can have inheritance relationships with other classes and therefore are organised in a hierarchical manner.

Relationship: This identifier may be select when teaching about concepts where there are entities which possess links with each other and where such links are relevant to the information being conveyed.
Example & Rationale: An example of when this identifier may be selected is when teaching about the departments of a company or organisation and how they relate with each other. This is because the departments of any organisation will have some relationship with other departments in the organisation (like being a sub department of or a parent department to) and such relationships usually need to be highlighted when studying the structure of an organisation.

Concept: This identifier may be selected when teaching about concepts where there is a need to describe or structure ideas. Such ideas will normally have relationships with themselves.
Example & Rationale: An example of when this identifier may be select is when teaching about the relationship between branches of subject of study, such as chemistry. This is because, a number of ideas usually contribute or make up a wider subject and these ideas will normally have relationships between themselves.

Object: This identifier may be selected when teaching about concepts where details about (or parts of) an object (whether physical or abstract) needs to be presented. This will usually be concepts where some sort of objectification highlights important aspects of the concepts under study.

Example & Rationale: An example of when this identifier may be select is when teaching about the parts of an internal combustion engine. This is because the internal combustion engine contains several components which are crucial to understanding how the engine works. Showing such parts in a diagram will help make it easier to understand how the different component of an engine interact with each other, and subsequently, how the engine works.

Component: This identifier may be selected when teaching about a concept where there is need to show the constituents of a system and in some cases, how they interact with each other.

Example & Rationale: An example of when this identifier may be select is when teaching about the parts of an internal combustion engine. This is because the internal combustion engine contains several components which are crucial to understanding how the engine works. Showing such parts in a diagram will help make it easier to understand how the different component of an engine interact with each other, and subsequently, how the engine works.

System: This identifier may be selected when teaching about a concept that involves an organised interaction of a set of entities or units or components. This could be about physical (tangible) components or entities or abstract ones.

Example & Rationale: An example of when this identifier may be selected is when learning about the components of a computer and how they interact with each other. This is because there are several components which work together to make up a computer system.

Set: This identifier may be selected when teaching about a concept where there is need to show the relationships between sets.

Example & Rationale: An example of when this identifier may be selected is when teaching about the similarities and differences between entities like fruit. This is because several entities may have attributes which are different to some and similar to others. Banana will have some vitamins that are similar to that of oranges and some that are not available in oranges and vice versa.

Software: This identifier may be selected when teaching about software that needs to be described. This will normally be some piece of a computer program or a description of such.
Example & Rationale: An example of when this identifier may be used is when teaching about classes and objects in object-oriented computer programming. This is because classes and objects are software components and a description of these using models help to enhance the learning experience.

Data: This identifier may be selected in situations where data needs to be depicted in a diagram. Based on the media taxonomy described in chapter five, diagrams are normally not used as a data visualisation media type but there are some media types that could be used to visualise data, in addition to the non-data aspects of the diagram. In such cases, this identifier could be selected.
Example & Rationale: An example of when this information identifier may be selected is when teaching about average temperature differences across the countries of the world. Countries can easily be shown using a diagram, but the average temperature data could be superimposed on a map using shades of a single colour or group of colours that represent the value of average temperature for each country.

Spatial: This identifier may be selected when teaching about concepts that have spatial attributes like position, area and size. It should be selected when models of these attributes are key to understanding the concepts being taught.
Example & Rationale: An example of when this identifier may be selected is when teaching about the planets and the solar system. This is because the planets and the solar system have spatial attributes such as size (which can be scaled) and have a definable position, related to each other.

Location: This identifier may be selected when locational information needs to be presented as part of learning. Such locational information may be geographical positions of places (using longitude & latitude).

Example & Rationale: An example of when this identifier may be selected is when teaching about geographic locations and/or any associated attributes such as road network, topology, etc. This is because geographic locations have spatial attributes such as size (which can be scaled) and topological attributes.

8.2.4 Descriptions for the Chart Identifiers

The descriptions for the diagram information identifiers are outlined as follows: -

Trend: This identifier may be selected when there is a need to illustrate the change of an attribute (such as data) over time.

Example & Rationale: An example of when this identifier may be selected is when learning about the human growth chart and the differences between boys and girls as they grow from birth until adult age. This is because the height data changes with time and therefore can be said to be a trend.

Record: This identifier may be selected when a record or records of something needs to be shown. This 'something' may be entities which have attributes which when considered together, may be regarded as a record.

Example & Rationale: An example of when this identifier may be selected is when outlining the attributes of several fruits. Such attributes may be the presence of a vitamin, the colour, the pH value, etc. This is because the fruit can be considered as a record of each of these attributes.

Properties: This identifier may be selected when there is a need to present information about entities that possess attributes. It may also be selected when there is a need to

present information which about a single entity or concept with varying properties or attribute values.
Example & Rationale: Similar to the record identifier, this identifier may be selected is when outlining the attributes of several fruits. Such attributes may be the presence of a vitamin, the colour, the pH value, etc. This is because these attributes can be considered as properties of fruits.

Comparison: This identifier may be selected when two or more data points need to be compared. The intention here may be to compare how two attributes have changed over time.
Example & Rationale: An example of when this identifier may be selected is when there is a need to show how the volume of import and exports of a country compare to each other, particularly over time. This is because there are two attributes which have changed over time with a need to understand how that change occurred.

Correlation: This identifier may be selected when there's need to explain concepts that study the relationship between factors. Such concepts may require a visual representation of the interrelationship between the factors under study.
Example & Rationale: An example of when this identifier may be selected is when there is a need to show the relationship between one’s level of education and their salary. This is because there are two factors which have a relationship with each other.

Relationship: This identifier may be selected when connections between data or the attributes of several data points need to be examined.
Example & Rationale: An example of when this identifier may be selected is when there is a need to show the relationship between one’s level of education and their salary. This is because there are two factors which have a relationship with each other.

Discrete: This identifier may be selected when teaching about concepts that deal with distinct (or categorical) data.

Example & Rationale: An example of when this identifier may be selected is when there is a need to show information about the number of patients in each hospital ward. This is because this deals with discrete data which is the hospital wards.

Continuous: This identifier may be selected when teaching about concepts that deal with data that has a range, regarded as continuous data.

Example & Rationale: An example of when this identifier may be selected is when there is a need to show information about all the scores in a test and the number of people that attained each score. This is because the data here is of a continuous nature.

8.3 Suggestion of alternative media types

The media selection framework described in chapter six was designed to produce only one media type for every educational concept. During the experiments presented in chapter seven, one of the participants suggested that having more than one media type output might be useful. One such case of usefulness might be situations where it is expensive or impractical to develop the media type that has been recommended. For example, it may take more time and resources to develop an animated diagram, compared to a static diagram. In such a scenario, the user may want to know what other media type(s) they could consider using, as a trade-off. Given that the recommended media is calculated as the mode of all media types that map to the selected identifiers, this feature can be implemented by regarding the mode of the media type list as the recommended media type and the next two most occurring media types as the alternative media types. Using this mode method of recommending media types also means that it is possible for this framework to generate n number of alternative media types where n could be anything from 0 to the maximum number of unique media types that map to the selected information identifiers. The same process outlined in section 6.6 would be followed when generating the alternative media types, including the process for resolving multimodal outcomes.

8.4 Support for the VARK learning model

In the literature review, the VARK learning model was discussed. This model groups individuals into categories that represent how they best learn, based on sensory modalities. These four modalities are Visual, Auditory, Read/Write and Kinaesthetic. Given that the VARK learning model is based around sensory modalities (how information is received and processed by learners, and through what channels), it is possible to assign one or more VARK learning models to a media type. To provide support for the VARK learning model, all media types were tagged with one of the four VARK learning models according to their suitability for that model. When a learner prefers to learn using any media that depicts information using maps, spider diagrams, charts, graphs, flow charts, etc, they are said to be visual learners. From the hierarchical media taxonomy, the media types that fall into this category are charts and diagrams (and their subtypes). Therefore, all media types that are charts or diagrams are tagged as visual media types. When a learner has a preference for information that is heard or spoken, they are said to have an aural preference. All audio media types (such as speech, music, and ambient sound) were placed into this category and tagged as such. When a learner has a preference for information that is written, they are said to be read-write learners. The text media types (such as sentence, list, code, and formula) were placed into this category and tagged as such. The kinaesthetic modality refers to the “perceptual preference related to the use of experience and practice.” (Fleming and Mills, 1992). This may either be real or simulated. Fleming and Mills (1992) also stated that kinaesthetic learners prefer to learn "through concrete personal experiences, examples, practice or simulation”. Some of the examples they listed include videos of real things, practices, demonstrations, and simulations. From this, it can be said that animation (animated diagrams and charts) and videos fall into this category and were tagged as such.

The design of the VARK learning model makes it possible to attribute a VARK learning preference to every media type. Table 8.1 contains a list of all the main media types contained in the hierarchical media taxonomy, mapped to their attributed VARK learning preference.

Table 8.1: The main media types mapped to a VARK learning model

VARK learning model	**Media types (Hierarchical Media Taxonomy)**
Visual	Image, Chart, Diagram
Aural	Sound, Speech, Ambient Sound, Music
Read-Write	Text, Sentence, Formula, Source Code, List
Kinaesthetic	Animation, Animated Chart, Animated Diagram, Picture, Video

8.5 Support for media type retrofitting

Due to the possibility of a new media type being developed, it is important that any media section system is able to deal with any new forms of media. Without being able to do this, any media selection system will become obsolete whenever a new media type is created. The first step towards retrofitting a media type is to analyse the information presenting attributes and capabilities of the media type, using heuristics or guidelines for that media (if available). The next step is to identify a set of keywords (information identifiers) that encapsulate the information presenting attributes and capabilities of that media type. Where any of the identified keywords already exists in (or is a close match to) the known list of information identifiers, the existing one should be used. In the absence of that, new information identifiers can be created. Once the set of information identifiers have been created, they should be placed into the main list of information identifiers and the media type should be mapped to all of these identifiers. If one or more media types are already mapped to any of these information identifiers, care should be taken in deciding the position that the new media type should hold on that list. This should be based on which media type is more suited to that information identifier. Finally, the new media type should be placed in an appropriate position on the hierarchical media taxonomy tree and should be given a suitable VARK learning model tag, based on the VARK guidelines.

The media selection tool that was introduced in chapter six was developed without the possibility to add any new media type to it (without rewriting or adding new code to it). This means that any user of that tool will need very good knowledge of HTML and JavaScript in order to support newer forms of media. Given that there are a substantial number of educational material developers who have no knowledge of programming, it is therefore impractical for a subset of the intended users to use the tool to support new media types. As a result, a new system which can deal with new types of media, is needed. This should make it possible for an educational material developer to use the framework to work with new media types. Section 8.7 discusses such a system.

8.6 Targeting specific "devices"

Multimedia content is usually created for use on electronic devices such as PCs, smartphones, and tablets, however, multimedia can still be used on other "devices" like books. Certain devices do not permit the use of some types of media. For example, Klenner stated (2015), "it is impossible to use a video or audio clip on a simple sheet of paper". In this research, a "device" is defined as the medium on which a particular media type is displayed and from which its information is consumed. When a user intends to use this framework to select media types for a book, without some sort of device targeting, the framework might return a media recommendation that cannot be used on the book, for example, an animated diagram or a video. Three kinds of devices were therefore identified. These are Print, Screen and Audio devices.

Print: This device refers to any printed material such as books, newspapers, printed journals, magazines, etc. Any media type that can be used on such devices can be tagged as print media types. These include pictures, charts, diagrams, and all forms of the text media type (such as list, sentence, code, and formula).

Screen: This includes any electronic or computing ware that has a display with sufficient number of pixels (preferably coloured) through which information can be displayed. This includes smartphones, personal computers, or tablets with a sizeable screen (as a rough guide, anything around 400 by 400 pixels or more). In essence, any device that has a sizeable screen, relevant software to process the electronic media type formats and a graphics processor to push the information to a display would constitute a screen. Any media type that can be used on such devices can be tagged as screen media types. These include most media types such as animations, videos, pictures, charts, diagrams, and all forms of the text media type (such as list, sentence, code and formula).

Audio devices: This refers to any electronic ware that has the capacity to manage and play audio that has a frequency within the normal range of the human hearing. Examples include MP3 players, iPods, computers, smartphones, and tablets. Any media type that can be used on such devices can be tagged as audio media types. These include videos (that are accompanied with sound) and audio types (such as speech, music, and ambient sound).

Table 8.2 contains a list of the main media types that are part of the hierarchical media taxonomy, mapped to compatible devices.

Table 8.2: The main media types mapped to compatible devices

Device type	**Media types (Hierarchical Media Taxonomy)**
Print	Image, Chart, Picture, Diagram, Text, Sentence, Formula, Source Code, List
Screen	Image, Chart, Picture, Diagram, Text, Sentence, Formula, Source Code, List, Animation, Animated Chart, Animated Diagram, Video
Audio	Sound, Speech, Ambient Sound, Music, Video

8.7 The design of a new system

In chapter six, a media selection tool was developed for the purpose of simplifying the process of media selection using this media selection framework. The tool was built as a standalone HTML and JavaScript application which could be launched on any browser. However, one serious limitation of this approach is that it becomes difficult to modify or extend the framework. While a user who has very good knowledge of HTML and JavaScript might be able to do so (albeit with hours of coding needed), users who have no knowledge of HTML and JavaScript will be unable to do so. This also means that some of the needed changes which became apparent at the end of the initial evaluation would require many hours of work to retrofit into the system, even simple changes like adding a new media type. For this reason, it has become necessary to build a new system. Such a system should make it a lot easier to make improvements to the details of any information identifier, add or remove identifiers, retrofit the system with any new media types, and more. This section discusses the design of a new media selection system.

8.7.1 Requirements

In order to elicit the requirements of this system, we need to understand the aim of the system and who the users will be. As earlier discussed, the system needs to facilitate the selection of media types using the media selection framework developed. Therefore…

> *The aim of the system is to support the creation and management of hierarchical media types and information identifiers, and to use these to facilitate the media selection process for the development of effective educational materials.*

The users of this system will be anyone who intends to develop educational materials. These users will come from very different fields and some of them will not be computer or information technology experts. It is therefore necessary that the system is easy to understand and usable by anyone with a basic experience of how to browse the web. The next segment highlights the functional and non-functional requirements of the system. These have been numbered using the format FRn (where n is nth functional requirement) and NFRn where (where n is nth non-functional requirement).

Functional requirements

FR1. The media selection system shall allow users to add new media types into the database.
Why: This is to allow any user to include new media types into the system, thereby making it extensible.
Inputs: media name, description, media parent, VARK learning model, target device and sample media.

FR2. The system shall allow the user to view the details of an existing media type.
Why: A user may want some information about any or all or the media types already in the

system such as their parent, a sample image, etc.

Inputs: The media ID.

FR3. The system shall allow users to modify the details of an existing media type.

Why: A user may want to change the media name or its description.

Inputs: The media ID, any new details required.

FR4. The system shall allow users to delete a media type where no dependency exists (that is, where there is no media subtype available).

Why: A user may want to delete a media type that is no longer needed.

Inputs: The media ID.

FR5. The media selection system shall allow users to add new identifiers into the database.

Why: These are needed as the system will need to have a mapping to each media type.

Inputs: identifier name, description, list of media types to map this identifier to, priority setting for each media mapping.

FR6. The system shall allow the user to view the details of an information identifier.

Why: A user may want to view some details about one or more identifiers already in the system such as their media mappings or a description of this identifier.

Inputs: The identifier ID.

FR7. The system shall allow users to modify the details of an existing identifier on the database.

Why: A user may want to change the identifier media mappings, the priority setting of its mappings, its name or description.

Inputs: The identifier ID.

FR8. The system shall allow users to delete an information identifier.

Why: A user may want to delete an identifier type that is no longer needed.

Inputs: The identifier ID.

FR9. The system shall facilitate the selection of media types using the proposed media selection framework.

Why: This is the main purpose of the system and other requirements provide the necessary details to enable the system to perform a media selection.

Inputs: The relevant identifier IDs.

FR10. The system shall allow the user to tailor the media selection process to a learner's VARK learning model.

Why: A user may want to tailor the media selection process to a particular VARK learning preference.

Inputs: The required VARK learning preference(s).

FR11. The system shall allow the user to select media types that are targeted to specific display devices.

Why: A user may want to produce media that are suitable for specific types of devices. For example, the animated diagram cannot be used on a printed book.

Inputs: The required target device(s).

FR12. The system shall display a recommended media type and up to two alternative media types.

Why: The user may want more choices for several reasons, one of which is if the main recommendation is impractical to develop.

Inputs: The VARK learning preference(s), required target device(s) and the relevant identifiers.

Non-functional requirements

NFR1. Ease of use: The system should be easy to use by anyone with a basic understanding of how to browse a web.

NFR2. Reliability: The system should return reliable results, that is, the same results under the same conditions.

NFR3. Speed: The system should return the results in less than 3 seconds.

NFR4. Scalability: The system should be scalable. It should be possible to add as many media types and identifiers as needed without altering the performance, usability or reliability of the system.

8.7.2 Database design

The database is one of the most important aspects of the system because it provides persistent data storage which makes is possible for the framework to be improved and/or extended. In order to meet the requirements of the application, six tables were created. These tables were called target, media_target, media, identifier, identifier_media and vark_modality. An entity relationship diagram of these tables is shown in figure 8.1. The following are details about each database table and its columns: -

media: This table holds the details of a media type.

> *media_id*: This is the unique identifier for each media type.
>
> *media_name*: The name of this media type.
>
> *description*: A description of the media type.
>
> *modality_id*: This is the ID of the VARK learning preference to which this media type is associated.

parent: This is the ID of the media type which serves as the parent of this media type. For example, the media type image is the parent of a chart. If a media type has no parent (for example, the media types at the top of the hierarchy), this value will be null.

sample_url: A link to the storage location of a sample of this media type (the user needs to place the file in a server directory and specify the file name and extension.

vark_modality: This table holds details about VARK learning models.

modality_id: This is the unique identifier for each VARK learning model.

modality_name: The name of this VARK learning model.

identifier: This table holds details about the available information identifiers.

identifier_id: This is the unique identifier for each information identifier.

identifier_name: The name of this information identifier.

description: A description of this information identifier and examples of how/when to use it.

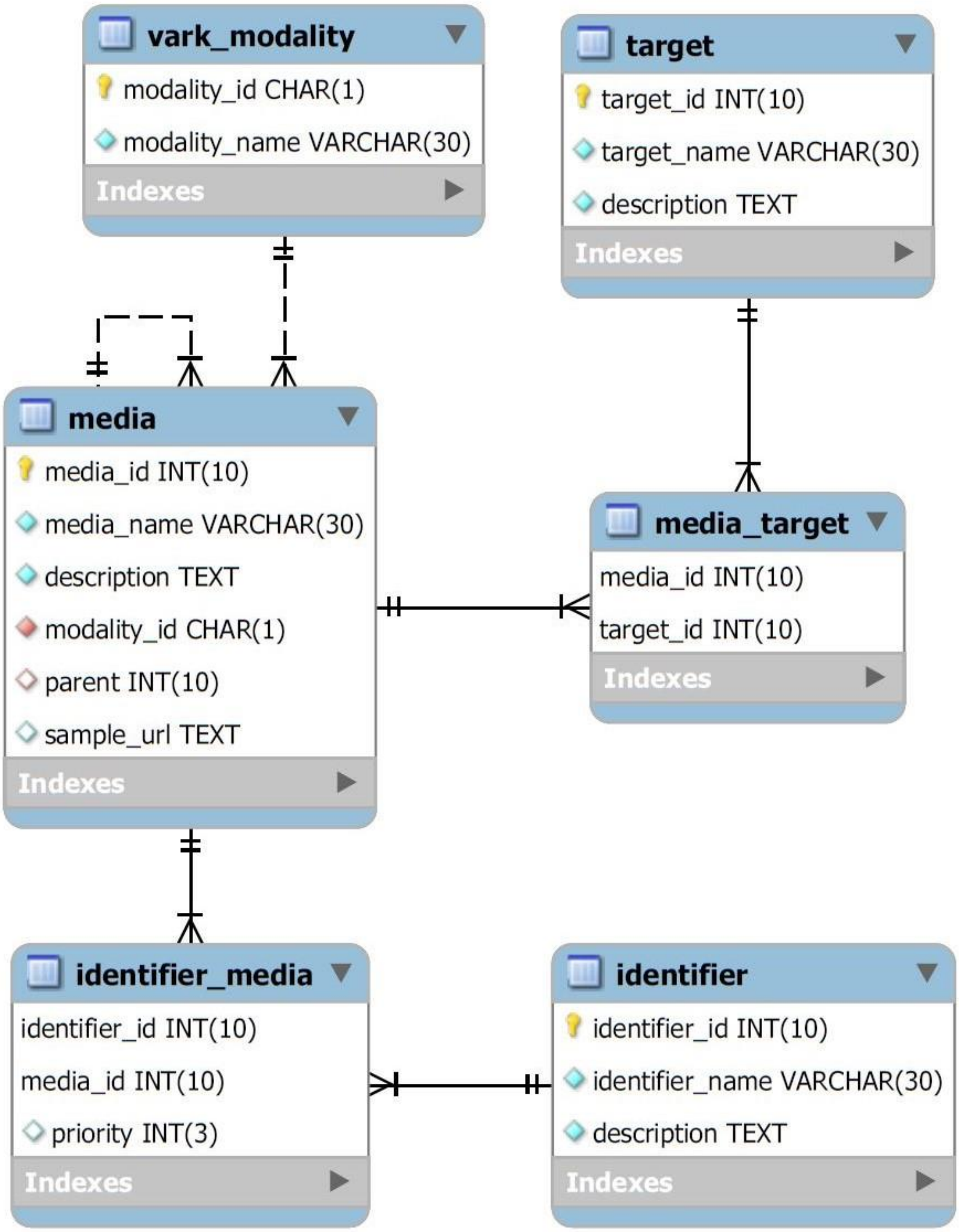


Figure 8.1: Entity relationship diagram of the application database

identifier_media: This table holds the mapping from information identifiers to media types.

identifier_id: The identifier_id for this identifier-to-media mapping.

media_id: The media_id for this identifier-to-media mapping.

priority: The priority setting for this identifier-to-media mapping. The media type with a higher priority is recommended when there is a 'multimodal' recommendation. Lower values of this column mean higher priority (the lowest possible value is 1).

target: This table is used to store all available target devices (the device on which a media can be displayed or used).

target_id: This is the unique identifier for each target device.

target_name: The name of this target device.

description: A description of this target device.

media_target: This table associates a media type with a target.

media_id: The media_id for this media-to-target mapping.

target_id: The target_id for this media-to-target mapping.

8.7.3 Application design

The application consists of a front-end (using HTML, CSS and JavaScript), a middle-tier (using PHP) and a backend (MySQL database). Development effort was channeled towards the functionality of the application, rather than the look and feel. The functionalities of the application were provided as menu options (hyperlinks) on the web page, as per the functional requirements. These menu options are discussed as follows: -

Adding new media types: To add a new media type, the user needs to specify the name of the media type, a description, the VARK modality that they are associating with this media type, the parent media type for this new media type and a selection of the target devices appropriate for this new media type.

Editing media types: To edit a media type, the user needs to first select the media type they want to edit from the list of all available media types and then view it. In the view option, the user can choose the edit option and change any of the details for this media type. These include the media name, the parent media type, the description, the VARK learning model and the target devices.

Deleting media types: To edit a media type, the user needs to first select the media type they want to edit from the list of all available media types and then click a delete button. They are asked to confirm deletion before the deletion is actioned. If the media type contains dependencies (that is, if there are other media types for which this media type is a parent), the deletion will not be allowed because that will break the hierarchical structure based on the media taxonomy described in chapter five.

Adding new identifiers: To add a new identifier, the user needs to specify the name of the identifier, a description (which should also contain one or more examples of how or when the identifier may be selected) and the list of media types to which this identifier is mapped. If more than one media mapping is selected, the user will be asked to set the priority level for each of the media mappings. The media mapping with the highest priority is given a priority value of 1 (higher integer values indicate lower priority). If there are n number of media mappings to this identifier, then the user will only be allowed to set a priority value that ranges from 1 – n for each mapping and the system ensures that no two mappings can have the same priority value by replacing the priority value of a mapping when this value is selected for another mapping. The identifier name, description, media mappings and priority values are then saved on the database.

Editing identifiers: To edit an identifier, the user needs to first select the identifier they want to edit from the list of all available identifiers and then view it. In the view option, the user can choose a partial edit option to edit just the name and description or they can choose the full edit option which allows them to edit not only the name and description but also the media mappings. Editing the media mapping allows the user to add new media mappings, delete existing media mappings or change the priority level of any media mappings. These are then saved on the database.

Deleting identifiers: To delete an identifier, the user needs to first select the identifier they want to delete, from the list of all available identifiers and then click the delete button. They are asked to confirm deletion before the deletion is actioned. This deletes the identifier and all mappings of this identifier to any media type.

Selecting media: Selecting media is the most important function of the system. This allows users to choose identifiers that relate to the learning concepts for which they are designing materials. The system then uses these identifiers to recommend a media type based on the rules of the media selection framework. The system recommends one main media type and two alternative media types. At launch of the media selection function, the system identifiers all known media types (stored in its database) that are at level 1 and level 2 of the media type hierarchy. Media types with no parents on this system are at level 1 and the media types that are direct descendants (children) of the level 1 media types are at level 2. The system then uses the collated media types to display a set of identifiers which the user is to choose from. The system does this by collating and displaying all the identifiers that have a mapping to the retrieved media types. A shortened description of each identifier is also displayed with the identifier. The user can click shortened description to view the complete description. A list of the available target devices and VARK learning models are also displayed. At this stage the user selects the learner's VARK preference(s), the target device(s) and the required identifiers. The VARK preference(s) can be ignored if the learner has no preference, if such preference is not known or if the user does not wish to tailor the media selection to any VARK learning model. This would cause the system to disregard VARK preferences altogether, during the selection process. The user can also select intended target device(s). If no target device is selected, the system disregards this option during the media selection process. Once all options (VARK learning preferences, target devices and identifiers) have been selected, the system uses the details to recommend one media type and two alternative media types. This begins with the system retrieving all media types that have a mapping with the selected identifiers. If one or more VARK learning preferences were selected, the system removes any media types that are not associated with the selected VARK learning preferences. Also, if one or more target devices were selected, the system removes any media types that are not associated with the selected target devices. Once this is done, the system calculates the statistical mode of all remaining media types. The most occurring media type becomes the recommended media type and the next two most occurring media types become the alternative media types. During the statistical mode calculation, the priority setting for each media type is also noted. This is done by keeping track of the lowest priority setting (lower priority setting means a higher priority) for each media type used during the selection process and storing that value for use if there is a multimodal result. If the result is multimodal, the system selects the media type which has the highest priority (lowest priority setting) as the recommended media type. At the end of the media selection process, the system checks to see if any of the recommended or alternative media types have descendants (sub types).

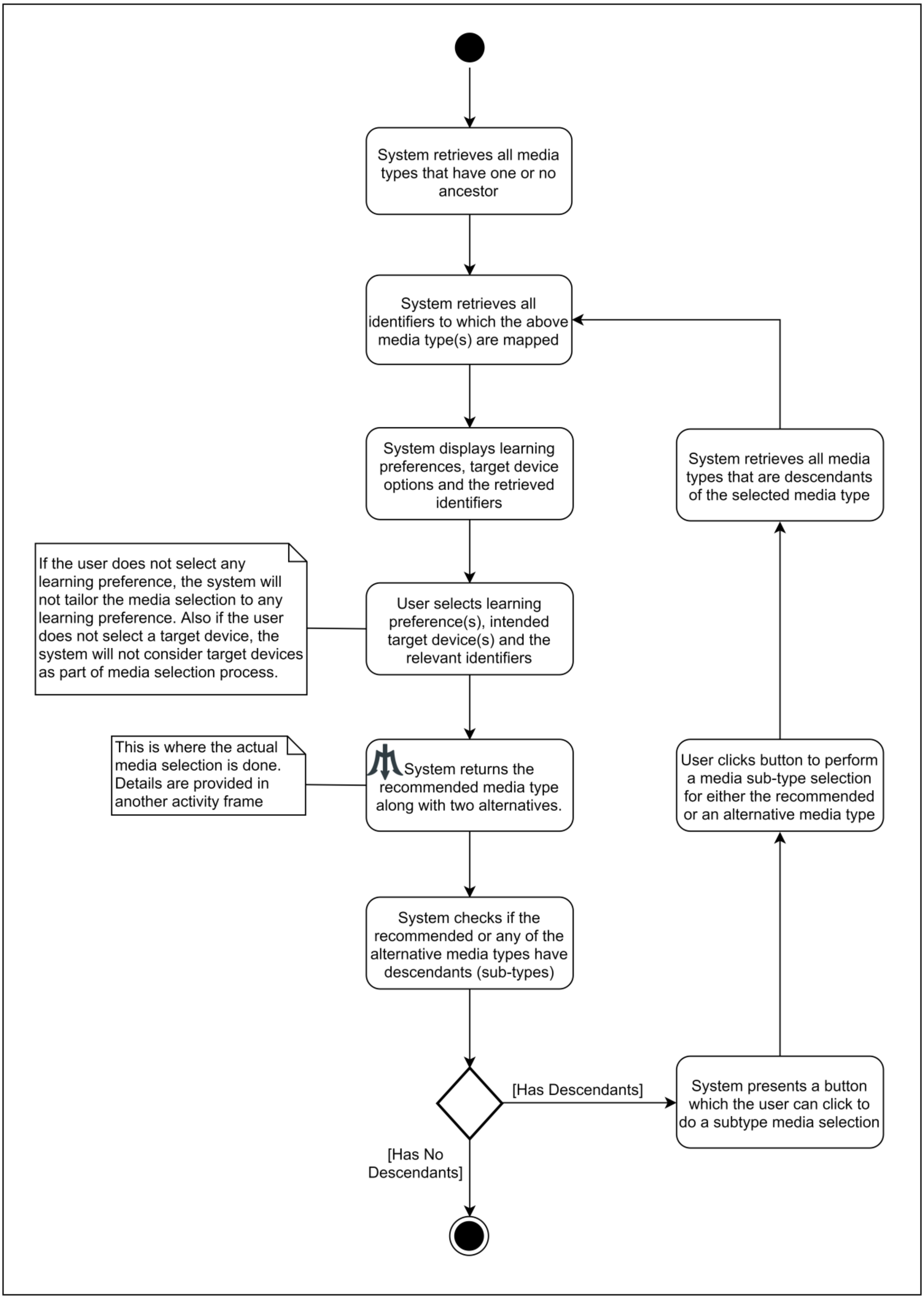
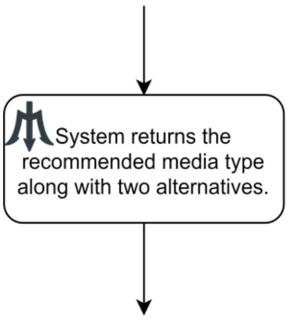


Figure 8.2: An activity diagram of the overall media selection process

The ones that do have sub types are given an option (using a clickable button) to repeat the media selection process on the sub types of that media type. The process continues until there is no other subtype media on which to perform the selection process. Figure 8.2 is an activity diagram of the process of media selection.



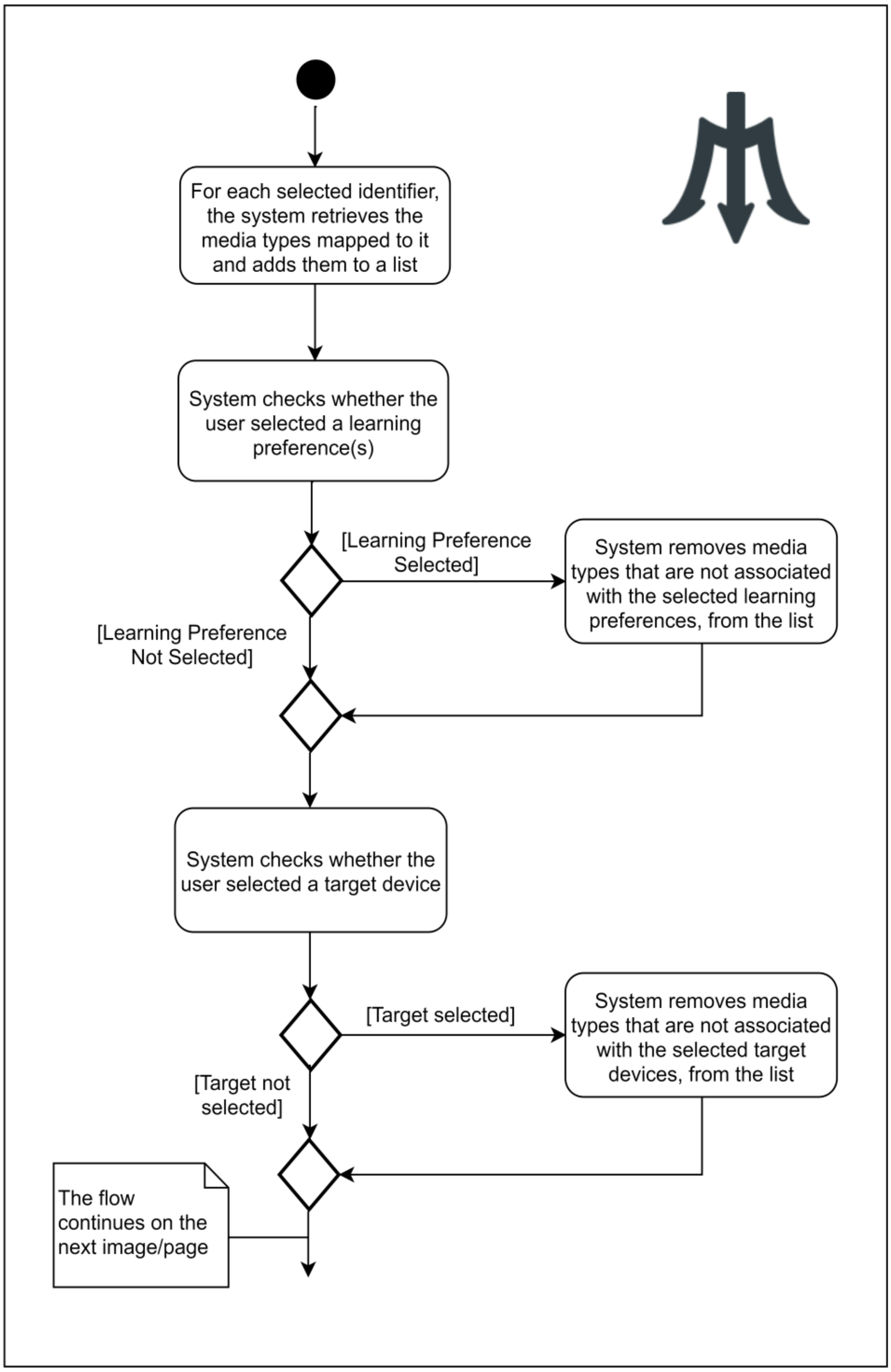


Figure 8.3: An activity diagram of the actual media selection algorithm

Figures 8.3 and 8.4 are activity diagrams showing the algorithm which is used by the system to return the recommended media (figure 8.4 is an extension of figure 8.3).

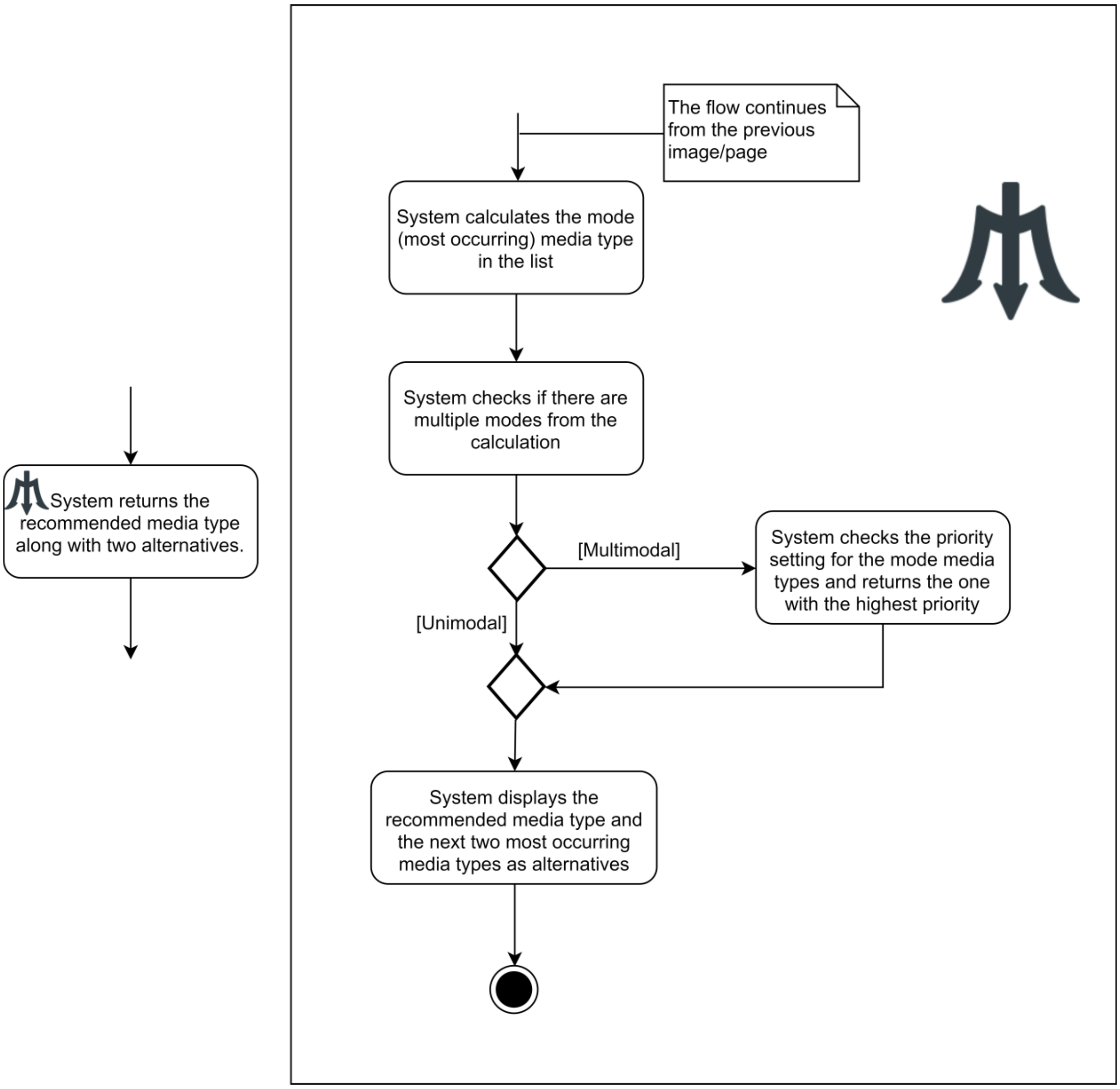


Figure 8.4: An activity diagram of the actual media selection algorithm (continuation)

8.7.4 Testing and deployment

Unit tests were performed on all functions in the code and observed errors were fixed. Subsequently, the application was black-box tested. This was done to ensure that all the functional and non-functional requirements were met. All the issues found were addressed, including issues with the interface. Once all tests were complete and the application was performing satisfactorily, the application was deployed to the web and can be accessed using this link https://ccddo.github.io/MediaSelection/. Screenshots are available at the appendix section and the full application code (including the HTML pages, PHP scripts, database table creation script and the SQL insertion scripts) are available on GitHub via this link https://github.com/ccddo/MediaSelection/releases/download/v1/MediaSelection.zip.

8.8 Summary

In chapter six, a method for media selection was proposed and was evaluated in chapter seven. During the evaluation of this method, several areas for improvement were identified. These include improvements to the information identifiers and descriptions (to make it easier for users to understand what the identifiers mean), support for alternative media type recommendation (to give the user more choice for reasons such as to select a media type that is easier to develop), support for learning models (allowing users to tailor the media selection to a learner's preference), support for media type retrofitting (allowing users to add any new media type when they become available) and support for device targeting (allowing the recommendation of media types based on the destination of the multimedia material). This chapter discussed these improvements. Given the nature of the changes, it was necessary to have a new application which provides all the functionalities required to support these changes. This chapter discussed the design and implementation of a new application. The next chapter discusses the design and results of some experiments which aims to ensure that the changes made to the media selection framework have not affected its validity and usability.

9 Media Selection: Re-Evaluation

9.1 Introduction

In chapter six, a method for the selection of media for the development of educational materials was discussed. This method was designed to work with the hierarchical media taxonomy which was discussed in chapter five. Chapter seven discussed an experiment which was designed to validate the media selection method. In essence, the aim was to investigate whether using this method for selecting media improved learning. An already developed learning material was acquired. This was used for the control group in the experiment. The same learning material was then modified using the media selection framework, to ensure that all the recommended media types were used. The modified learning material was used for the experimental group. Participants were asked to study the materials presented for their groups and were subsequently asked to do a test. An independent samples t-test was performed, and statistically significant differences were found. Chapter seven also discusses a reliability experiment (to assess whether there was consistency in the recommendations from the media selection method) and a usability experiment (to assess whether users found the media selection method usable). The results showed that although improved learning was observed (evidenced by higher test scores), several improvements to the method were needed. These include improvements to the definitions of the information identifiers, addition of the option for alternative media type recommendations, addition of the possibility to tailor a media selection to a particular learning preference, addition of the possibility to retrofit the method with newer media types, and addition of the possibility to target the media selection to a particular device. Chapter eight discussed the changes that were made to the media selection method and the design of a new media selection tool which supports the changes that were made. These changes have made it necessary to reassess the media selection method. This chapter discusses two experiments aimed re-evaluating the media selection method. The aim of the first experiment is to revalidate the media selection method. In essence, is there *still* a statistically significant improvement in learning when learners learn from an educational material that was developed using the media selection framework, compared to a learning material which is not compliant with this method? The aim of the second experiment is to reassess the usability of the media selection method and the web-based selection system that was developed in the previous chapter. The procedures followed in conducting these experiments are discussed in the next sections.

9.2 Revalidation Experiment

Given the changes that were made to some parts of the media selection method including the addition of new functionalities, it is important that it is revalidated to ensure that it still works as intended. The aim of this revalidation experiment is to assess whether the media selection method *still* improves learning. From this, we can formulate the hypotheses for this experiment.

- **Null hypotheses** (H_0): The use of the improved media selection framework does not lead to better learning and retention when used to design educational materials.
- **Alternative hypothesis** (H_1): The use of the improved media selection framework leads to better learning and retention when used to design educational materials.

Among the most widely employed methods of evidencing or measuring learning are tests, assignments, and exams. Many schools, colleges and universities employ this method. In this experiment, the participants would be asked to write a test as evidence of learning. Two groups of learners (a control and an experimental group) would be presented with two sets of learning materials. The control group would be learning from a pre-existing material and the experimental group would be learning from a modified version of the pre-existing learning material. The modification of the pre-existing learning material would be done using the framework procedures. The participants would then be asked to undertake learning tests and the test scores from both experiments would be compared. Higher scores in learning tests for participants in the experimental group would be regarded as an indication of improved learning.

9.2.1 The Design

An independent design was used for the revalidation experiment. Two groups were involved in this experiment, a control group, and an experimental group. The learning material used for this experiment was obtained from khanacademy.org. Two versions of this learning material were made available. The first version was based on the original content from the learning website and the second material was based on modifications that were made to bring it in compliance with the media selection method, without any change to the underlying learning concepts and goals. Participants from each group would learn using the educational material made for their group and then subsequently write a test to measure the learning that occurred. One drawback of the experiments conducted in chapter seven was that prior knowledge of the field or subject was not measured, hence it was not possible to accurately tell if the participants' test performance was due to engagement with the learning material or due to prior knowledge in the field. Therefore, in this revalidation experiments, participants were asked to do a pre-test (by completing the test questions) before beginning the learning task. After completing the learning tasks, they would be asked to do a post-test and improvements in test score would be regarded as evidence of learning that occurred as a result of engagement with the learning material.

9.2.2 The Learning Material

The learning material used was obtained from the KhanAcademy learning website (khanacademy.org) and contained various science concepts. A copy of the learning material was downloaded and stored on a local computer. This was done so that the learning material could not be modified by the web authors during the experiments. The materials were then analysed, and the learning tasks and goals were outlined. The recommended media types for these tasks were then selected and these were checked against the original material. Some changes were made to the pre-existing learning materials and a copy of the modified material was saved, whilst retaining the original content. The changes made to the material include the addition of some diagrams and animation, but care was taken not to alter the learning goals of the original material. More precisely, three diagrams and two animations (animated diagrams) were introduced in the experimental learning materials. The pre-existing material was assigned to the control group and the modified version was assigned to the experimental group.

9.2.3 The Test Procedure

Thirty-four participants were recruited and split into two different groups. There were seventeen participants per group. The participants were University students and were chosen at random from the University's library. On the test day, participants were welcomed and then asked to read some information about the study and give their consent. Afterwards, participants were asked to complete a profile questionnaire which contained questions such as age group and gender. Next, participants were directed to the VARK website to answer questions about their learning preferences (http://vark-learn.com/the-vark-questionnaire/) after which their learning preference scores were calculated and displayed. The VARK scores were obtained. Next, participants were asked to do a pre-test. This was done to assess the participant's prior knowledge in the subject (it is important that any post-learning test score can be attributed to the learning material). After completing the pre-test questions, the participants were asked to study the learning materials for their assigned group. The learning activity was timed and had to be completed within twenty minutes and any participant exceeding that time would have to be stopped. The reason for timing the learning activity was to ensure that all participants learned under the same conditions. Once the learning activity was complete, the participants were asked to complete a post-test. The participant's performance in this test was used as an indication of learning. The learning retention test had to be completed within ten minutes and participants would be stopped if they exceeded that time limit. Again, the reason for timing the test was to ensure that all participants were exposed to the same conditions. Finally, all participants were debriefed and were given the opportunity to ask questions about the research study. They were also provided an email address to contact, should they require further information about the study or wish to withdraw and have their data deleted.

9.3 Usability Experiment

Chapter eight discussed the development of a new media selection tool which was necessary, due to the improvements that highlighted during the first evaluation of the media selection method in chapter seven. The potential complexity associated with the media selection framework makes performing a media selection by hand impractical for continuous use. It is therefore necessary that users find the web-based tool easy to learn and easy to use. This section and its sub sections discuss an experiment aimed at assessing whether users found the framework easy to learn, usable and useful. The next few sections discuss the design, the participants, and the procedure of this experiment.

9.3.1 The Design

In order to gather feedback on the use of the framework and web tool, it is necessary that participants perform some media selection tasks using the tool. Although it is possible to perform a media selection task by use of pen and paper, given how large the supported media types can get and process required to obtain a recommended media, the web-based tool is required to make the process easier. Participants in this experiment would be asked to use the web-based tool that was developed, to perform some media selection tasks. This means that the participants need to be taught how to use the framework and the web-based tool. After learning to use the framework and the web application, participants would be asked to use it to select appropriate media types for some learning tasks. Once completed, they would be asked questions about the perceived ease of use, ease of learning and perceived usefulness of the framework.

9.3.2 The Procedure

Nine participants were recruited for this experiment. The participants were known to the researcher through research work or research-related meetups and had agreed to participate in the experiment. One criterion for selecting participants is that they should have taught or been involved in the design of learning materials at some point in the past or at the present. On the test day, participants were welcomed and then asked to read some information about the study and give their consent. Afterwards, participants were asked to complete a profile questionnaire which contained questions such as age group and gender. All the participants confirmed that they had at some point been involved in teaching and/or learning material designing. A PowerPoint slideshow was used to train the participants to use the media selection framework. The PowerPoint explained how the media selection framework could be used by hand for the media selection task and then introduced the web-based application which the participants were also taught how to use. After the training, participants were presented with ten learning tasks and were asked to use the media selection web application to identify suitable media types for the learning tasks. At the end of the media selection process, participants were asked to complete a scaled-down version of Lund's USE questionnaire (Lund, 2001) aimed at assessing the perceived ease of use and usability of the tool and the framework. Finally, all participants were debriefed and were given the opportunity to ask questions about the research study. They were also provided an email address to contact, should they require further information about the study or wish to withdraw and have their data deleted.

9.4 Results

The changes made to the framework and the media selection web application made it necessary to revalidate the framework and web application. The previous sections discussed the design and procedure of a revalidation experiment (which was aimed at assessing whether using the media selection framework led to improvements in learning) and a usability experiment (aimed at assessing how easy to learn, usable and useful the framework and web application are). The results of these experiments are outlined in the next few sections.

9.4.1 Validity Test Results

There were seventeen participants in each group. Both the pre-test and post-test consisted of the same questions (ten in number). A point was given for each correctly answered question and no point was given for questions either not answered correctly or questions skipped. For the pre-test scores, the participants in the control group achieved an average (mean) of 5.471 (standard error, 0.298) and the standard deviation was 1.23, while the participants in the experimental group achieved an average (mean) of 5.647 (standard error, 0.521) and the standard deviation was 2.148. For the post-test scores, the participants in the control group achieved an average (mean) of 6.529 (standard error, 0.31) and the standard deviation was 1.28, while the participants in the experimental group achieved an average (mean) of 7.647 (standard error, 0.32) and the standard deviation was 1.32. The data from both the pre-test and post-test were tested for normality using Shapiro-Wilk’s test and both the pre-test and post-test data for both groups satisfied the assumption of normality. Figures 9.1 to 9.4 show normal Q-Q plots for each of the pre-test scores and post-test scores for the control and experimental groups, using IBM SPSS.

Between the pre-test and the post-test, participants in the control group showed an average improvement in test scores of 1.05. Improvements in scores for this group ranged between 0 (six participants recorded no learning, that is, the test scores were unchanged after the learning activity) and 3. For the experimental group, participants showed an average improvement in test scores of 2.0, which is almost one point above the control group. Improvements in scores for the experimental group ranged between 0 (four participants recorded no learning, that is, the test scores were unchanged after the learning activity) and 6, with most of them gaining 4 or less points.

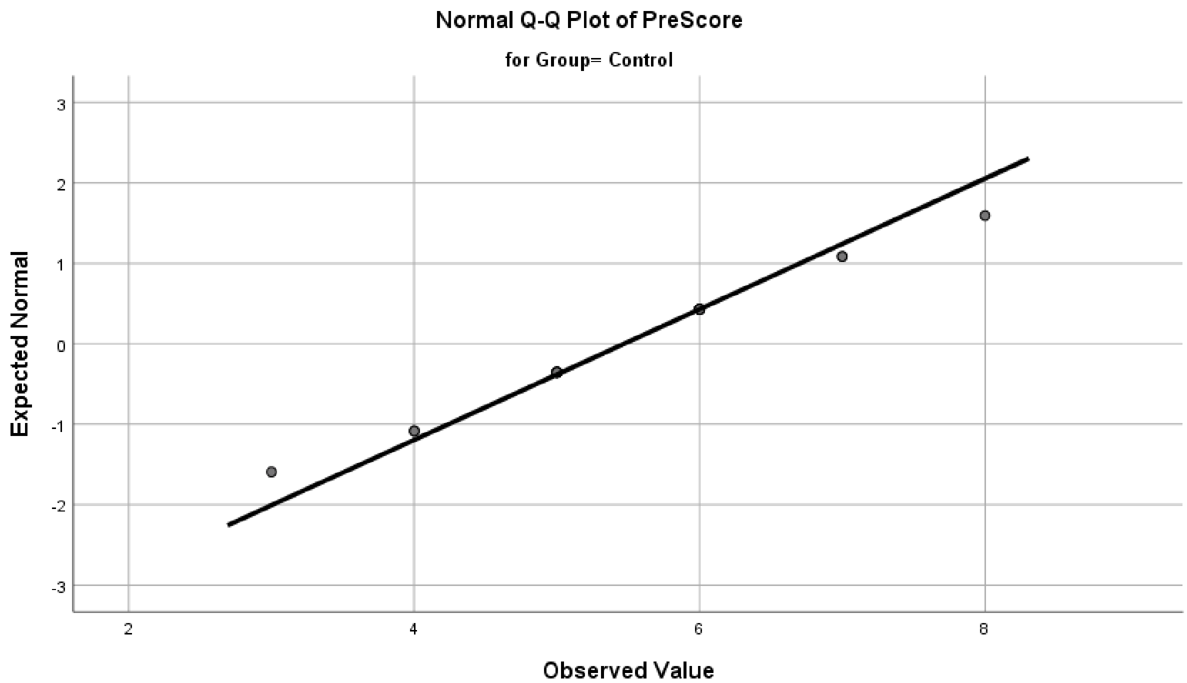


Figure 9.1: Normal Q-Q plot of pre-test scores for the control group

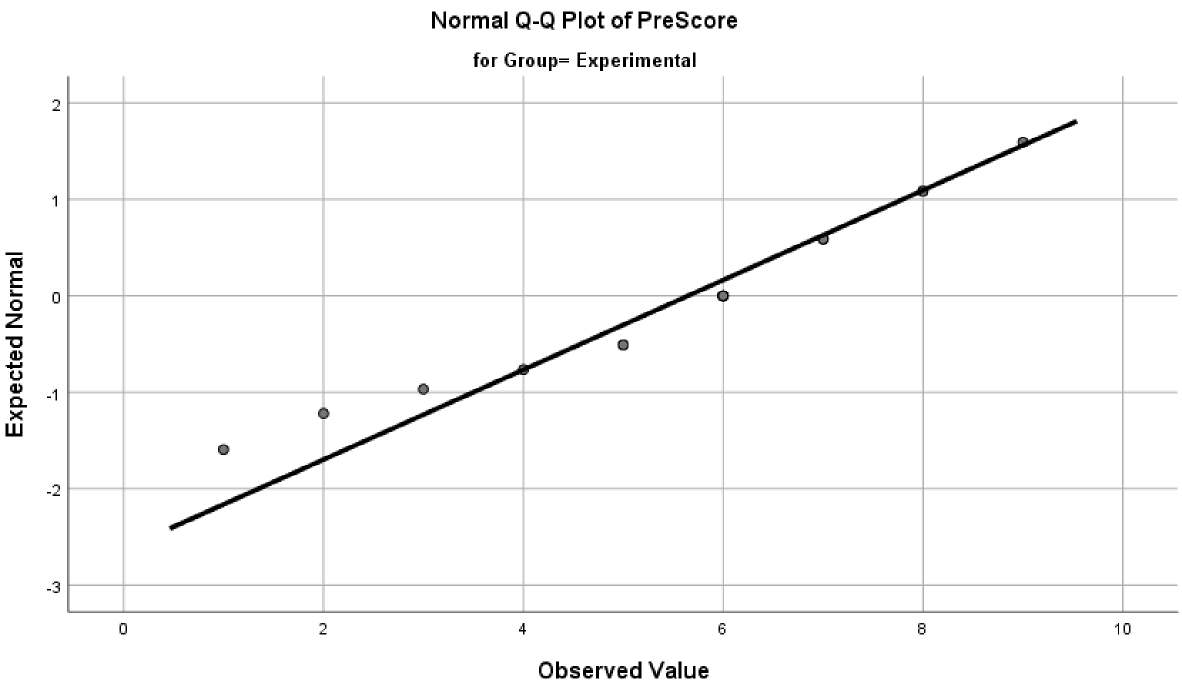


Figure 9.2: Normal Q-Q plot of pre-test scores for the experimental group

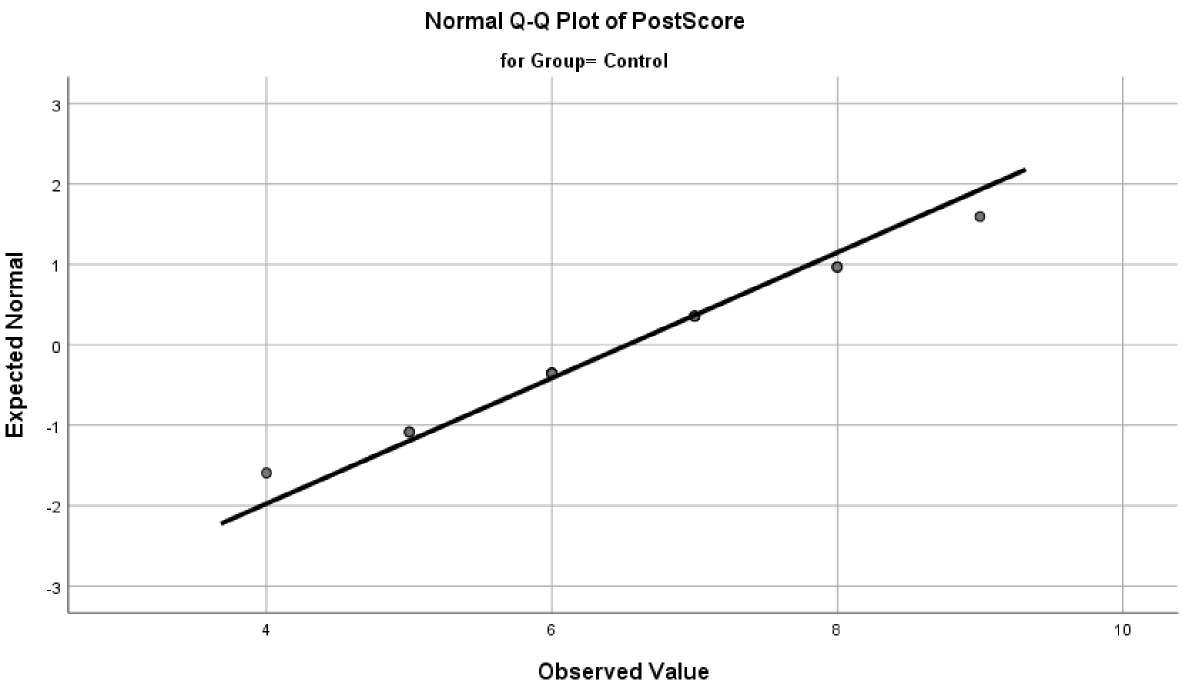


Figure 9.3: Normal Q-Q plot of post-test scores for the control group

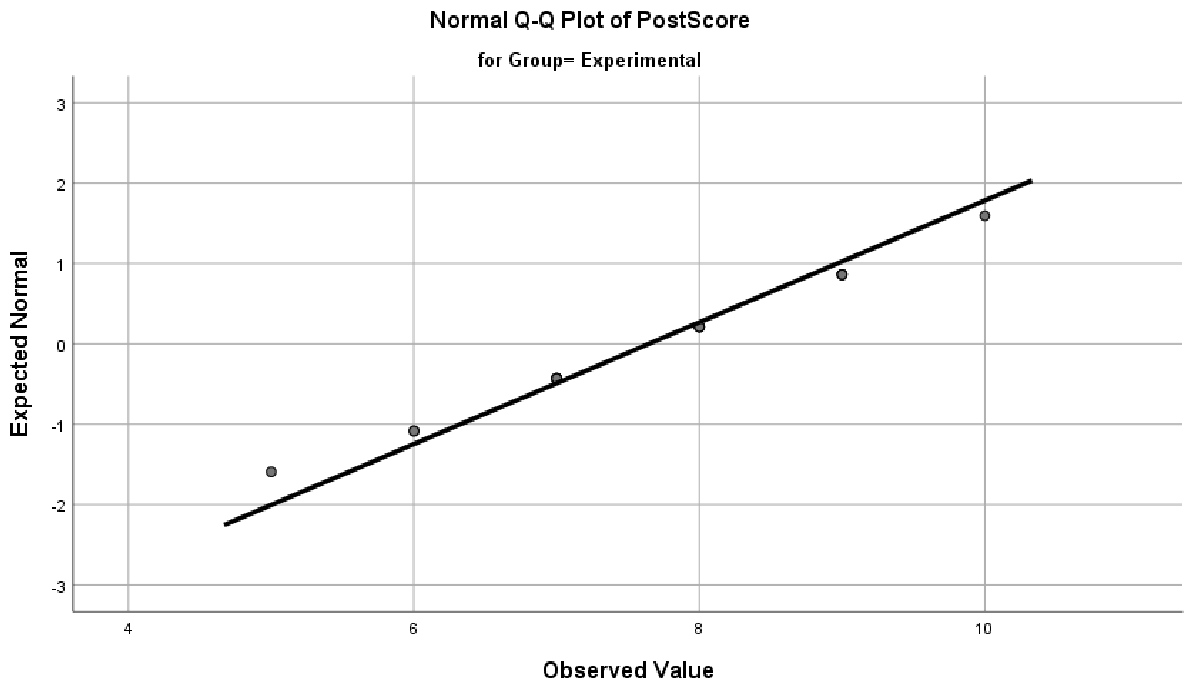


Figure 9.4: Normal Q-Q plot of post-test scores for the experimental group

The results show that the average post-test score (the score obtained after participants engaged with the learning material) for the experimental group was a numerically higher the average post-test score for the control group. To test whether this higher test scores of the experimental group, compared to the control group, was statistically significantly, an independent samples t-test was done. The assumption of homogeneity of variances was tested and satisfied using Levene's test, F (32) = 0.04, p = 0.844 (> 0.05) and the data were checked again for normality using skewness and kurtosis and were found to be normal (skewness < |2.0| and kurtosis < |9.0|), based on Schmider, Ziegler, Danay, Beyer and Bühner's guidelines (2010). The results of the independent samples t-test showed that the higher mean scores of the experimental group was statistically significant, compared to the control group, t (32) = -2.51, p = 0.018 (< 0.05). Cohen's d was calculated to be 0.859, which is a large effect size, based on Cohen's (1992) guidelines (Cohen's guidelines suggests that a d value of 0.2 should be considered a small effect size, 0.5 a medium effect size, and 0.8 a large effect size). This means that we can reject the null hypothesis that the use of the improved media selection framework does not lead to better learning and retention and accept the alternative hypothesis which states that the use of the improved media selection framework leads to better learning and retention when used to design educational materials.

9.4.2 Usability Test Results

In the media selection task for the usability test, the participants were presented with ten learning tasks and were asked to use the media selection application to select the relevant media types for the tasks. The resulting media recommendations for each participant was checked and a correct recommendation was given a score of 1 while an incorrect recommendation was given a score of 0. The sum of the media selection scores of the nine participants ranged between 4 and 10 (M = 7.33, SD = 1.94).

The usability questionnaire was a trimmed down version of Lund's USE questionnaire (2001) with the scale ranging from strongly disagree (1) to strongly agree (7). Table 9.1 shows the frequency distribution (in percentage) of the USE questionnaire data from the nine participants. The positive column represents ratings from 5 - 7 (those that tended to agree, agreed, or strongly agreed with the statement), the neutral column represents ratings for 4 (those with a neutral opinion about the statement), while the negative column represents ratings for 1 - 3 (those that tended to disagree, disagreed, or strongly disagreed with the statement).

Table 9.1: Frequency distribution of the USE questionnaire data

	POSITIVE	NEUTRAL	NEGATIVE
USEFULNESS			
It helps me be more effective	88.9%	0.0%	11.1%
It helps me to be more productive	88.9%	0.0%	11.1%
It is useful	88.9%	0.0%	11.1%
It saves me time when I use it	77.8%	11.1%	11.1%
EASE OF USE			
It is easy to use	77.8%	11.1%	11.1%
It is user friendly	77.8%	11.1%	11.1%
Using it is effortless	77.8%	11.1%	11.1%
EASE OF LEARNING			
I learned to use it quickly	66.7%	11.1%	22.2%
I easily remember how to use it	88.9%	0.0%	11.1%
It is easy to learn to use	77.8%	11.1%	11.1%
SATISFACTION			
I am satisfied with it	77.8%	0.0%	22.2%
I would recommend it to a colleague	77.8%	11.1%	11.1%
It works the way I want it to work	66.7%	33.3%	0.0%
I feel I need to have it	66.7%	11.1%	22.2%

9.5 Discussion

Several studies have shown that multimedia can improve learning (for example, Mayer, 2003; Butcher, 2014; Pate and Posey, 2016; Moradi, Khazai, and Moradi, 2017) which have been explained by theories such as dual coding (Clark and Paivio, 1991). Although it has been well established that the use of multimedia can lead to improvements in learning, there is very little information (beyond guidelines) about the specific media type to use for a defined learning task. This means that multimedia material developers tend to use any media type that they consider suitable (see chapter four for more details) and we know that using the wrong media type can prevent inhibit in a multiple of ways. To solve this problem, a method for educational media selection was developed in chapter six. The experiments conducted in chapter seven showed that there were improvements in learning however, some issues were identified during the usability experiments. In light of this, the framework was modified, and a new web-based tool was created, with support for the improvements. The validity experiments in this section were necessary, so as to revalidate the framework, ensuring that the changes made did not invalidate its core functionality. To ensure that the results were not affected by the prior knowledge of the participants, a pre-test was performed. Between the pre-test and post-test for each group, most participants recorded an improvement in learning. Statistically significant differences were observed between those who learned using original learning material developed and those who learned using the modified learning material. The results of this revalidation experiment have shown that by having a methodical approach to media selection, learning can be improved.

The usability experiment required participants to use the media selection tool to perform some media selection tasks. In comparison with the earlier experiments detailed in chapter seven, there were better scores with the media selection correctness. In essence, more participants were able to correctly select a media type using the media selection method, compared to the previous experiments. It is likely that this can be attributed to the improvements made to the descriptions of the information identifiers, thereby decreasing the likelihood that they will be misunderstood by the users. In terms of the perceived usefulness, ease of use and the usability, there were overall positive responses from the USE questionnaire. From table 9.1, it can be seen that participants thought the method helped them become more effective, more productive and considered the method useful (88.9%). To a slightly lesser extent, participants thought it saved them time (77.8%). Moving on to its ease of use, 77.8% of the participants had positive responses to its ease of use, user friendliness and thought using it was effortless. The lowest positive scores were obtained in the section that asked how quickly it was to learn to use it. This could be because it requires a fair amount of effort (reading) to learn what each information identifier represents, however, as users continue to use it, they are very likely to remember the descriptions of each information identifier without resorting to the descriptive texts and examples. In the last section, about satisfaction, 77.8% had positive responses when asked whether they were satisfied with it and whether they would recommend it to a colleague.

9.5.1 Learning preference observations

One of the changes made to the media selection framework (described in chapter eight) was the ability to tailor the media selection process to a learner's preference based on the VARK model. This new feature presented the opportunity to contribute to the discourse on the effects of tailoring learning materials to a learner's preference, on learning experience and performance. Due to the difficulty of having to design one learning material for each participant (tailored to their learning preference), it was the decided that the data for the experimental participants will be separated into two groups – one containing the data for participants that have learning preferences which match the modified material (the 'tailored' group) and the other containing the data for participants that have learning preferences which did not match the learning material (the 'non-tailored' group). The changes made to the original learning material during the experiments earlier described, were the addition of four static diagrams and one animated diagram. Based on the VARK model, static diagrams are preferred by visual learners and animations are preferred by kinaesthetic learners, therefore, the learning material could be said to be tailored to the preferences of visual and kinaesthetic learners. Thirteen participants from the experimental group had either a visual preference, a kinaesthetic preference or both, while four participants had other learning preferences (such as aural and read-write). This is normal as some studies have shown that visual and kinaesthetic learners are usually the majority (for example, Kharb, Samanta, Jindal and Singh, 2013). The data for these participants were separated and analysed. The tailored group obtained an average score of 5.54 on the pre-test and 7.85 on the post-test (a difference of 2.31), while the non-tailored group obtained an average score of 6 on the pre-test and 7 on the post-test (a difference of 1.0). Although the sample size, particularly for the non-tailored group, is small, it shows that those in the tailored group achieved better learning than those in the non-tailored group. This is an interesting observation because it shows that there may be some benefits to tailoring learning materials to learners' preferences, although this is still debated by researchers (see section 2.5 for a review). If anything, more research is needed to investigate this observation and to understand the circumstances under which learners might experience improvements in learning when the learning material is tailored to their preferences and the circumstances under which this might not happen.

9.6 Summary

Multimedia is known to improve learning, however, there is evidence that the type of media used in the development of educational materials is crucial to learning performance. It cannot be assumed that any combination of media will result in improved learning (Grech, 2018) and there is evidence for this (for example, Bhowmick et. al., 2007; Sahasrabudhe and Kanungo, 2014). Therefore, the selection of media plays a very important role in multimedia learning because selecting inappropriate media types could inhibit the learning process. Chapter six introduced a method for the selection of media in the design of educational material and this media selection method was validated in chapter seven. The experiments aimed to assess whether the media selection method improves learning, whether users can correctly use the media selection framework to select appropriate media types and how usable the method and web-based tool are. Following this experiment, changes were made to the method in chapter eight and this chapter presented the results of a revalidation and usability experiment. Several findings emerged from this experiment. Firstly, it was found that employing the use of the media selection framework in the design of learning materials resulted in improvements in learning. Secondly, compared to the previous experiments, participants were able to better select media types using the web-based media selection tool. It is believed that the improvements to the descriptions of the information identifiers played a part in this outcome. Thirdly, when the data from the experimental group was analysed, it was found that the users who had learning preferences that matched the learning materials performed slightly better in learning test compared to those who had learning preferences which did not match the learning material. This finding highlights the need for more research in order to investigate the circumstances under which a learner might experience improvements in learning when the learning material is tailored to their preference and the circumstances under which this might not happen. In the next chapter, some case studies on the use of the media selection framework in the development of educational materials are discussed.

10 Case Studies of Multimedia Development

10.1 Introduction

Chapter six outlined the development of a media selection framework. This was evaluated in experiments presented in chapter seven. The outcome of the experiments showed that although there was evidence of improved learning when the framework was used to design learning materials, there were necessary changes which had to be made to the framework. Chapter eight discussed the changes that were made to the framework and the design of a new system that supported the changes that were made. In the previous chapter, the framework was re-evaluated, and the results showed that there was still evidence of improved learning. This chapter aims to illustrate the use of the media selection framework in the design of educational multimedia materials. The design of two educational multimedia materials is presented in this chapter. A group of learners were asked to learn from the materials and then subsequently asked to evaluate them. The data collected from the evaluation of the multimedia materials are also discussed.

10.2 The case study format

Case studies are widely used in research and come in different forms. One of the definitions of a case study, as obtained from the Lexico dictionary, which is powered by Oxford’s free English dictionary (https://www.lexico.com/en/definition/case_study), is “a particular instance of something used or analysed in order to illustrate a thesis or principle”. This is also known as an illustrative case study, and this is the type of case study used in this chapter. The aim of the case study is to illustrate the use of the media selection framework in the development of educational materials and gather feedback from users (learners) about what they think of the multimedia material. Two case studies are presented from two subject areas and the development of an educational material on one topic in each of the fields is discussed. The topics were kept simple so that no background knowledge will be required in order to engage with the learning material. Participants were recruited and asked to study and then evaluate the learning materials with a focus on the use of media on the materials. The next two sections discuss the case studies.

10.3 Case Study 1: The Law of Demand and Supply

In this case study, an educational material in the field of economics was developed. The topic was on the law of demand and supply. This was chosen because it was important that the topic was simple enough to not require background knowledge from the participants who will be studying the materials and so that it does not take a lot of time to study as this may cause participants to 'switch off'. In the next section, the development of the educational material is discussed.

10.3.1 Setting out the tasks

Before using the media selection framework, it is very important that some task analysis is done. The task analysis is used to fully establish what the communication goals are, the preconditions (if any), the tasks and subtasks required for the learning process. The following are the learning tasks required for the educational multimedia material.

T1. Define the law of demand

T2. State any assumptions for the law of demand

T3 Explain with an example how quantity demanded changes with price

T4. Define the law of supply

T5 State any assumptions for the law of supply

T6. Explain with an example how quantity supplied changes with price

10.3.2 Selecting the information identifiers and media types

For each task, a set of information identifiers will be selected at least once (the media selection process can be done more than once for a task). This section outlines each of the identified tasks and outlines the selected identifiers with reasons.

Task 1: Define the law of demand:

The selected identifiers are: - message

Reason: This identifier is used for defining concepts. As the law of demand needs to be defined, this identifier was selected.

The recommended media for this set of identifiers is sentence, therefore the definition of the law of demand will be presented using the **sentence** media type.

Task 2: State any assumptions for the law of demand:

The selected identifiers are: - message

Reason: This identifier is used for presenting descriptive messages therefore this identifier was selected because the assumptions are going to be descriptive.

The recommended media for this set of identifiers is sentence therefore stating the assumptions of the law of demand will be presented using the **sentence** media type.

Task 3: Explain with an example how quantity demanded changes with price:

The selected identifiers are: - message

Reason: This identifier is used for explaining concepts therefore it was selected because how quantity demanded changes with price will need to be explained.

The recommended media for this set of identifiers is sentence therefore explaining how quantity demanded changes with price will be done using the **sentence** media type.

For this task, another identifier selection is required so the process is repeated.

Selection 2: The selected identifiers are: - data

Reason: This is because examples that illustrate how quantity demanded changes with price require the use of data.

The recommended media for this set of identifiers is Chart, however the Chart type has subtypes so we are prompted by the system to do a subtype selection. The identifiers selected in the subtype stage are record (required as we need to show several records of price and their associated quantity demanded) and properties (each record has got price and quantity demanded as properties).

The recommended media for this set of identifiers is **Table** so we use a table to show several records of price and quantity demanded.

Selection 3: The selected identifiers are: - trend

Reason: This is because how quantity demanded changes with price needs to be illustrated.

The recommended media for this set of identifiers is **Line Chart**, therefore we use a line chart to show the relationship between price and quantity demanded.

Task 4: Define the law of supply.

The selected identifiers are: - message

Reason: This identifier is used for defining concepts. As the law of supply needs to be defined, this identifier was selected.

The recommended media for this set of identifiers is sentence, therefore the definition of the law of supply will be presented using the **sentence** media type.

Task 5: State any assumptions for the law of supply.

The selected identifiers are: - message

Reason: This identifier is used for presenting descriptive messages therefore this identifier was selected because the assumptions are going to be descriptive.

The recommended media for this set of identifiers is sentence therefore stating the assumptions of the law of supply will be presented using the **sentence** media type.

Task 6: Explain with an example how quantity supplied changes with price:

The selected identifiers are: - message

Reason: This identifier is used for explaining concepts therefore it was selected because how quantity supplied changes with price will need to be explained.

The recommended media for this set of identifiers is sentence therefore explaining how quantity supplied changes with price will be done using the **sentence** media type.

For this task, another identifier selection is required so the process is repeated.

Selection 2: The selected identifiers are: - data

Reason: This is because examples that illustrate how quantity supplied changes with price require the use of data.

The recommended media for this set of identifiers is Chart, however the Chart type has subtypes so we are prompted by the system to do a subtype selection. The identifiers selected in the subtype stage are record (required as we need to show several records of price and their associated quantity supplied) and properties (each record has got price and quantity supplied as properties).

The recommended media for this set of identifiers is **Table** so we use a table to show several records of price and quantity supplied.

Selection 3: The selected identifiers are: - trend

Reason: This is because how quantity supplied changes with price needs to be illustrated.

The recommended media for this set of identifiers is **Line Chart**, therefore we use a line chart to show the relationship between price and quantity supplied.

10.3.3 Developing and presenting the educational material

Using the media recommendations from the media selection process, the multimedia material was developed into a PowerPoint, containing the recommended media. A copy of the PowerPoint is available at the appendix section. Users were asked to learn from the material. This learning session was not timed, and no assessment of learning was conducted. The sole aim was to get users to engage with the material and then provide some feedback on it. The next session discusses the user evaluation of the multimedia material.

10.3.4 Multimedia evaluation

At the end of the learning task, eleven participants were asked to evaluate the multimedia material. The participants were asked to complete a simple questionnaire. There were three key questions in the questionnaire and participants had to assign ratings to these questions, on a scale of 1 – 10. These are: -

- Question 1: How easy was it to understand the information in this multimedia material? (1 = Hard, 10 = Easy).
- Question 2: Rate the overall appropriateness of multimedia (e.g., charts, diagrams, text, audio, etc) used in this multimedia material. (1 = Inappropriate, 10 = Appropriate).
- Question 3: Rate the overall design of this multimedia material. (1 = Bad, 10 = Good).

They were also asked to provide some comments about the multimedia material. The ratings given to question 1 were between 8 and 10 (mean = 9.45). The data is provided in figure 10.1. Participants generally found it easy to understand the information in the material. Similarly, the ratings given to question 2 (appropriateness of the multimedia used) were between 8 and 10 (mean = 9.36). The data is provided in figure 10.2. In terms of the overall design, participant ratings were between 9 and 10 (mean = 9.64). The data is provided in figure 10.3.

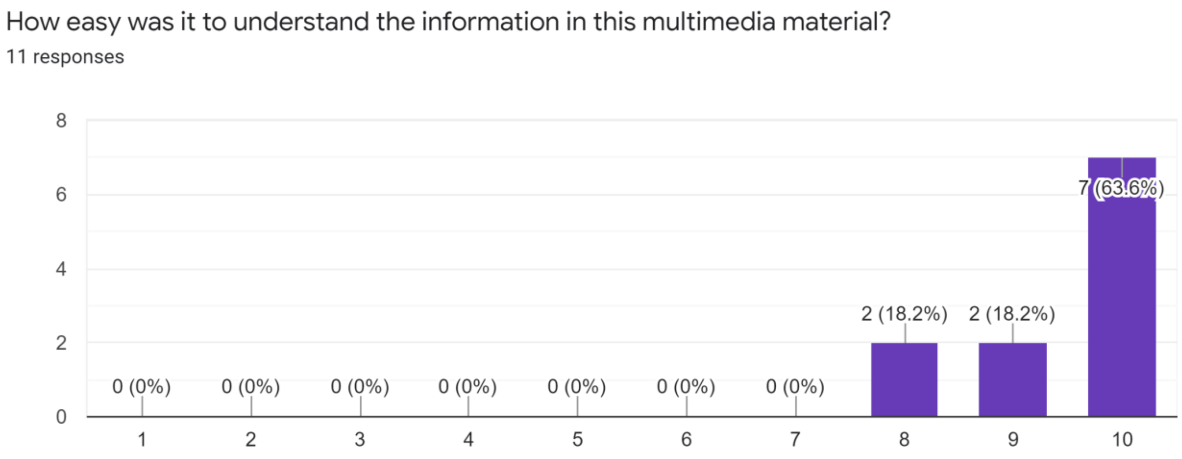


Figure 10.1: Ease of understanding information in multimedia material (Demand & Supply)

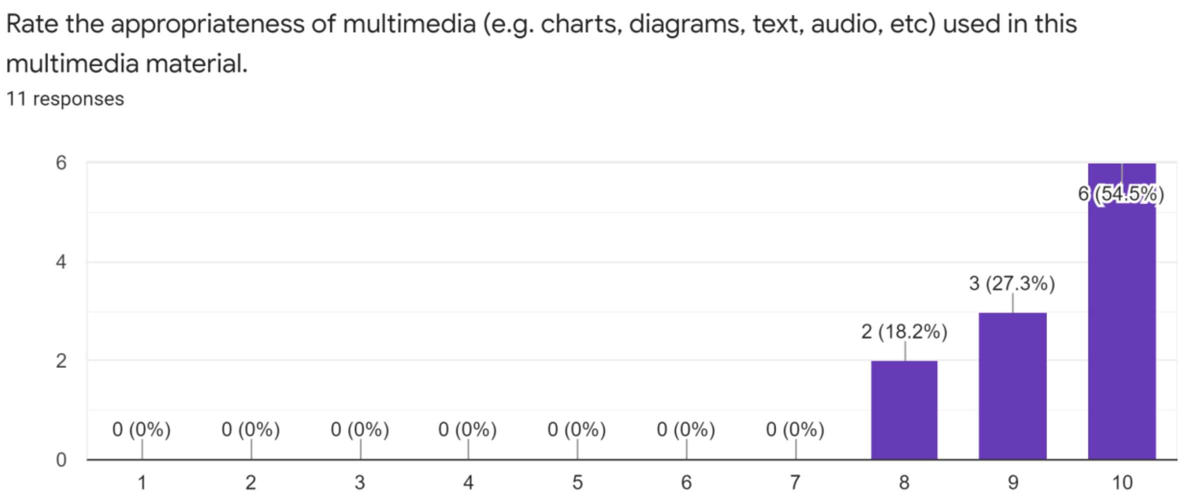


Figure 10.2: Appropriateness of the multimedia (Demand & Supply)

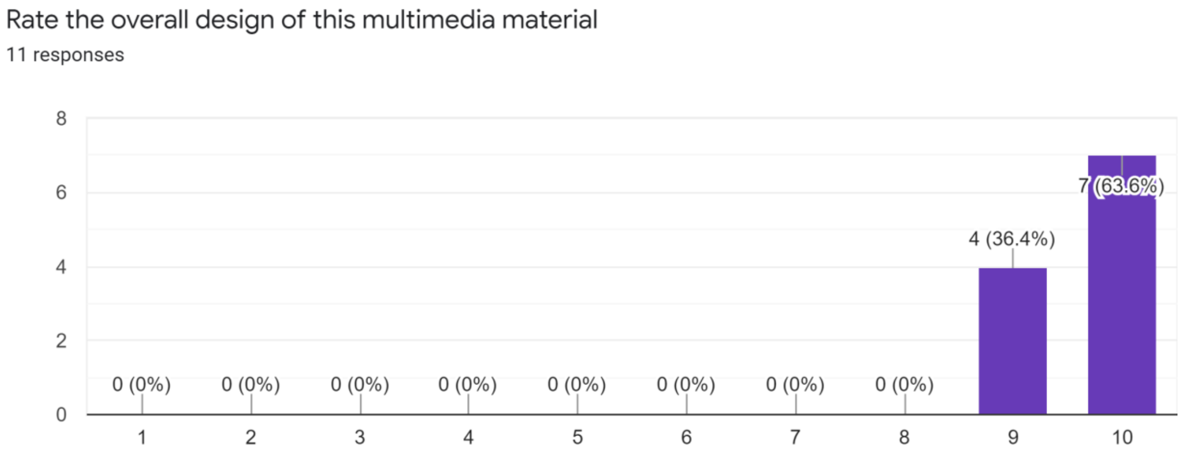


Figure 10.3: Rating of overall design of the multimedia material (Demand & Supply)

Some of the comments received are as follows: -

“It is very clear and easy to understand”

“It was concise and to the point. The use of texts and graphical representation was a good mix.”

“The material provided a clear picture of the law of demand and supply”

“Easy to understand and straightforward.”

“The visuals on the material aided the reader's understanding.”

“It was simple enough for me to understand, it had examples that explained better and the graph was just superb.”

“The media material was very appropriate and easy to use and understand”

10.4 Case Study 2: Classes and Objects

In this case study, an educational material in the field of computer software development was developed. The topic was classes and objects. Again, this was chosen because it is necessary that the topic is simple enough to not require background knowledge from the participants who will be studying the materials and so that it does not take a lot of time to study as this may cause participants to switch off. In the next section, the development of the educational material is discussed.

10.4.1 Setting out the tasks

Before using the framework, it is very important that some task analysis is done. The task analysis is used to fully establish what the communication goals are, the preconditions (if any), the tasks and subtasks required for the learning process. The following are the tasks required for the educational multimedia material.

T1. Define an object.

T2. Give an example of an object.

T3. State the characteristics of objects.

T4. Give examples of the characteristics of objects.

T5. Explain what parameters are.

T6. Define a software object.

T7. Define a software class.

T8. Explain the link between classes and objects.

T9. Describe the structure of software classes.

10.4.2 Selecting the information identifiers and media types

For each task, a set of information identifiers will be selected at least once (the media selection process can be done more than once for a task). This section outlines each of the identified tasks and outlines the selected identifiers with reasons.

Task 1: Define an object.

The selected identifiers are: - message

Reason: This identifier is used for defining concepts; therefore, this identifier was selected.

The recommended media for this set of identifiers is sentence, therefore the definition of objects will be presented using the **sentence** media type.

Task 2: Give an example of an object.

The selected identifiers are: - object, static

Reason: Object was selected because this task is about a physical item and static was selected because motion is not necessary to be able to identify or exemplify the object.

The recommended media for this set of identifiers is picture, therefore an example of an object will be illustrated using the **picture** media type.

Task 3: State the characteristics of objects.

The selected identifiers are: - requirements, message

Reason: Requirements was selected because the characteristics of anything is what is required to make that thing what it is and message was selected because stating the characteristics of anything involves providing descriptive information.

The recommended media for this set of identifiers is list, therefore the characteristics of objects will be presented using the **list** media type.

Task 4: Give examples of the characteristics of objects.

The selected identifiers are: - message

Reason: This identifier is used for informational messages therefore, this identifier was selected.

The recommended media for this set of identifiers is sentence, therefore examples of the characteristics of objects will be presented using the **sentence** media type.

For this task, another identifier selection is required so the process is repeated.

Selection 2: The selected identifiers are: object and static.

Reason: Object was selected because this task is about examples of the characteristics of a physical item and static was selected because motion is not involved in this case.

The recommended media for this set of identifiers is picture, therefore examples of the characteristics of objects will be illustrated using the **picture** media type.

Task 5: Explain what parameters are.

The selected identifiers are: - message

Reason: This identifier is used for defining or explaining concepts; therefore, this identifier was selected.

The recommended media for this set of identifiers is sentence, therefore the explanation of parameters will be presented using the **sentence** media type.

Task 6: Define a software object.

The selected identifiers are: - message

Reason: This identifier is used for defining or explaining concepts; therefore, this identifier was selected.

The recommended media for this set of identifiers is sentence, therefore the definition of a software object will be presented using the **sentence** media type.

Task 7: Define a software class.

The selected identifiers are: - message

Reason: This identifier is used for defining or explaining concepts; therefore, this identifier was selected.

The recommended media for this set of identifiers is sentence, therefore the definition of a software class will be presented using the **sentence** media type.

Task 8: Explain the link between classes and objects.

The selected identifiers are: - message

Reason: This identifier is used for defining or explaining concepts; therefore, this identifier was selected.

The recommended media for this set of identifiers is sentence, therefore an explanation of the link between classes and objects will be presented using the **sentence** media type.

Task 9: Describe the structure of software classes.

The selected identifiers are: - object, model, static

Reason: Object was selected because the intention is to describe the structure of something. Model was selected because software structure is an abstract concept and static was selected because dynamics are not involved.

The recommended media for this set of identifiers is diagram, but the diagram media type has subtypes so there is a prompt to select a subtype.

The selected identifiers for the subtype selection process are: - object, software.

Reason: Object was selected for the same reason as in the first selection stage and software was selected because we are dealing with a software concept.

The recommended media for this set of identifiers is **UML Diagram** therefore a UML Diagram will be used to describe the structure of software classes.

10.4.3 Developing and presenting the educational material

Using the media recommendations from the media selection process, the multimedia material was developed into a PowerPoint, containing the recommended media. A copy of the PowerPoint is available at the appendix section. Users were asked to learn from the material. This learning session was not timed, and no assessment of learning was conducted. The sole aim was to get users to engage with the material and then provide some feedback on it. The next session discusses the user evaluation of the multimedia material.

10.4.4 Multimedia evaluation

At the end of the learning task, ten participants were asked to evaluate the multimedia material. The participants were asked to complete a simple questionnaire. There were three key questions in the questionnaire and participants had to assign ratings to these questions, on a scale of 1 – 10. These are: -

- Question 1: How easy was it to understand the information in this multimedia material? (1 = Hard, 10 = Easy).
- Question 2: Rate the overall appropriateness of multimedia (e.g. charts, diagrams, text, audio, etc) used in this multimedia material. (1 = Inappropriate, 10 = Appropriate).
- Question 3: Rate the overall design of this multimedia material. (1 = Bad, 10 = Good).

They were also asked to provide some comments about the multimedia material. The ratings given to question 1 were between 6 and 10 (mean = 8.4). The data is provided in figure 10.4. Participants generally found it easy to understand the information in the material, however, this was a lower rating than in the previous case study. Similarly, the ratings given to question 2 (appropriateness of the multimedia used) were between 6 and 10 (mean = 8.3). The data is provided in figure 10.5. In terms of the overall design, participant ratings were between 6 and 10 (mean = 8.7). The data is provided in figure 10.6.

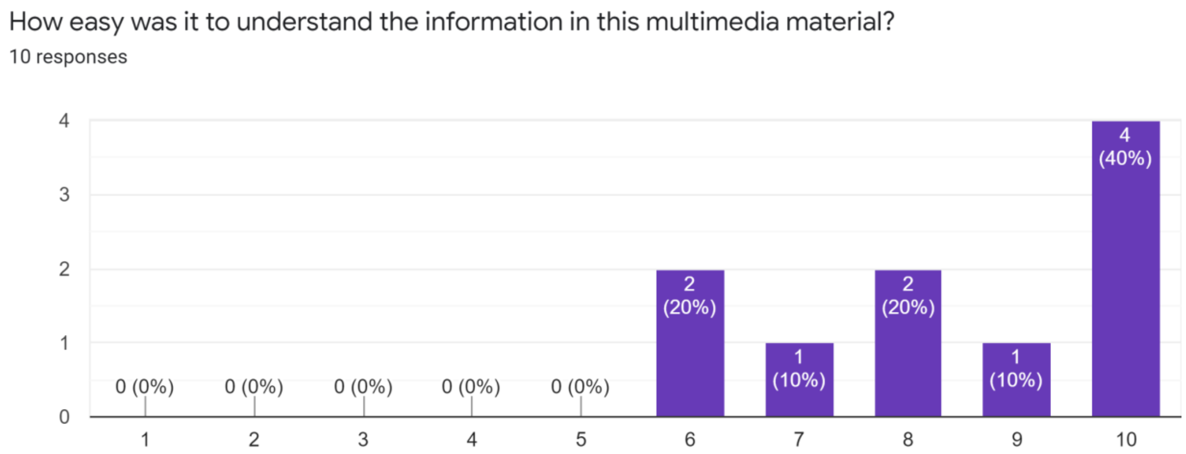


Figure 10.4: Ease of understanding information in multimedia material (Classes & Objects)

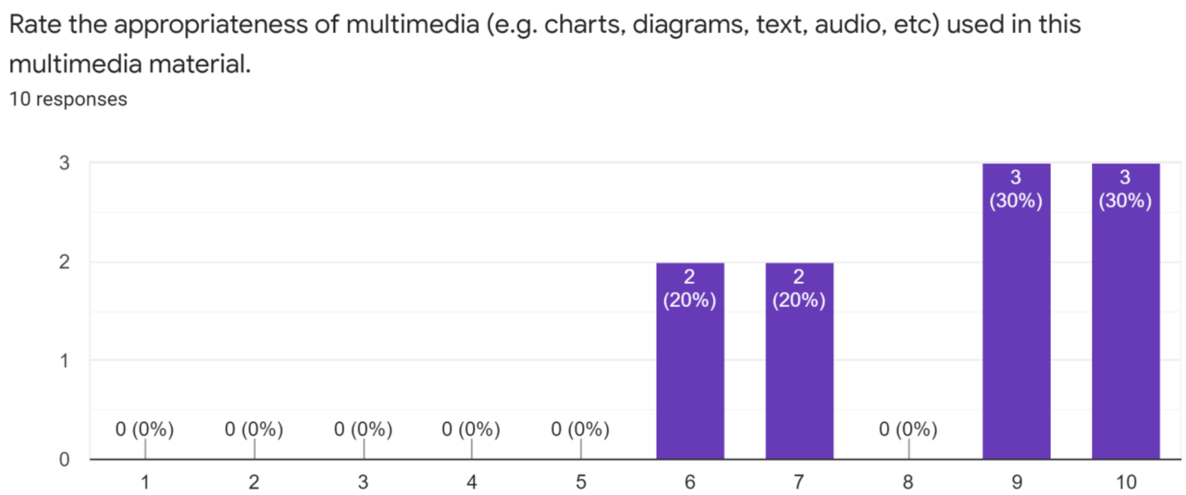


Figure 10.5: Appropriateness of the multimedia (Classes & Objects)

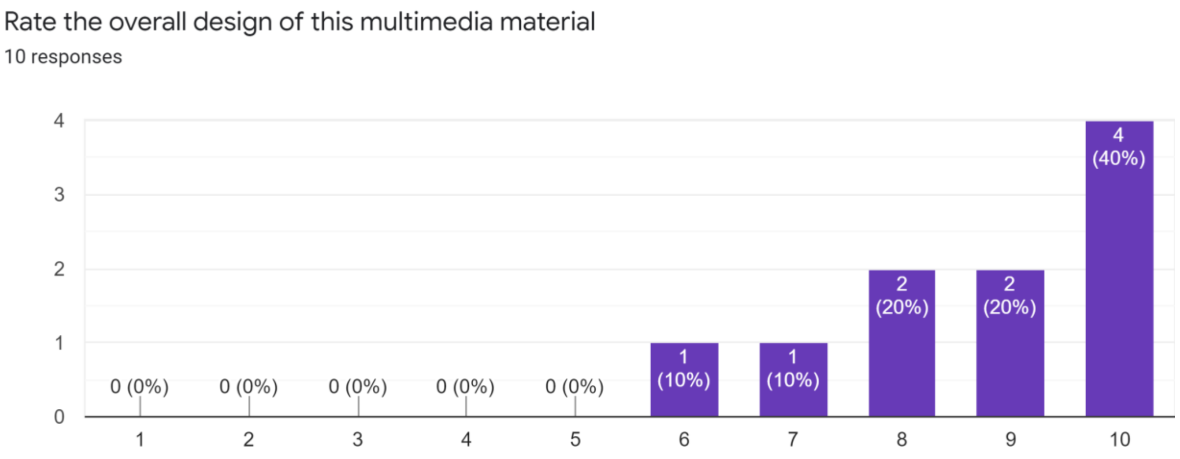


Figure 10.6: Rating of overall design of the multimedia material (Classes & Objects)

Some of the comments received are as follows: -

"Well-structured and easy to understand"

"A very good material and easy to understand."

"Too much text which were mostly definitions of terms. To someone unfamiliar with the subject matter, it might take a few reads to register."

"Found the material very informative and illustrative."

"Simplified yet detailed."

"It was easy to understand."

"It took me a while to see the similarities between the physical object and software object."

"Quite easy to understand despite the details."

10.5 Summary

This chapter presented two case studies to illustrate the use of the media selection framework in the design of educational multimedia materials. The chapter details the development of educational material from the process of setting out the tasks to the media selection process. A group of learners were asked to learn from the materials and then subsequently asked to evaluate them. The data collected from the evaluation of the multimedia materials were also discussed. In general, the participants were pleased with the use of multimedia in the educational materials.

11 Research Evaluation and Conclusion

11.1 Introduction

The previous chapter demonstrated the use of the media selection framework in the design of educational multimedia materials. Two educational multimedia materials were designed, and the process of selecting the media types for these was explained. The chapter also discussed an evaluation of the designed multimedia material. This is the final chapter of the thesis. It begins by summarising research and the individual chapters of the thesis. The research contributions are then highlighted in the sections following the overview of the research. As with any major undertaking, some problems were encountered, and this chapter briefly discusses them. Some limitations of this research were also highlighted. Finally, the chapter outlines some suggestions for future research work.

11.2 Overview of the research

Multimedia has the potential to improve learning and numerous studies have shown that learning can be improved when multimedia is used. This is sometime referred to as the multimedia effect. However, evidence shows that the choice of media plays an important role in this multimedia effect. In essence, one cannot assume that any media type or combination of media types would have positive effects on learning. So, the question is, what media or combinations of media would enhance learning for a particular learning content? Chapter one began by laying the foundations of the research. It discussed the background of the research, outlined the problem that the research intended to address, the aims and objectives, the theoretical basis, ethical considerations, and the expected outcomes of the research. Chapter two discussed relevant literature which is related to the research, including learning theories, learning styles and criticism of it, multimedia learning, multimedia design theories and why there is a need for a methodical approach to media selection to solve the problem of what media type (or combination of types) to use in a given situation. Chapter three outlined the research methodology of this research and the different stages of the research. Chapter four presented the results of a survey designed to understand how educators currently select multimedia in the design of educational materials. The results of the survey showed that a number of educators and learning material developers tend to rely on intuition and personal experience which could potentially inhibit learning, based on the literature review. Chapter five began by outlining the definition of media and multimedia which is used in this research. The chapter also began the process of the development of a framework for media selection by proposing a hierarchical media taxonomy which imposes an inheritance-like relationship between media types, like the inheritance relationships in object-oriented software development. The chapter also outlined the media types at level zero, level one and level two of the hierarchical media taxonomy and discussed an approach for resolving situations where a media type might fit into more than one category on the taxonomy. Chapter six discussed the development of a media selection framework. The framework development began by utilising the hierarchical media taxonomy that was proposed in chapter five, to create information identifiers which were mapped to recommended media types. A simple example of how to use the framework was also discussed. Chapter seven set out to validate the media selection framework. The essence of this validation was to ensure that learning was improved when the framework was used to develop educational materials. There were also experiments aimed at assessing whether users are able to correctly select media and whether they consider it usable. As a result of these experiments, some changes were needed. Chapter eight discussed the changes that were made to the media selection framework. These changes include improvements to the information identifiers, support for media type retrofitting, support for alternative media type recommendations, the ability to tailor the media selection process to a learner's preference and the ability to target the media selection process to a device. Chapter nine re-evaluated the media selection framework, given that changes were made to it following the initial experiments. It was found that learning was still improved and that users were able to better select media types with it. One other finding was that there was a small improvement in learning when the learning material was tailored to the learner's preference (although this finding came from a small sample size). Chapter ten discussed some case studies which were designed to illustrate the use of the media selection framework in the design of educational materials. Feedback was solicited from learner who evaluated the multimedia material, and the feedback was generally positive. Finally, this chapter concludes the research work, outlines the research contributions, the problems encountered and suggestions for future work.

11.3 Research contributions

Some contributions to knowledge have emerged from the research and the following sub-sections discuss these.

11.3.1 Hierarchical Media Taxonomy

Often, media types are not considered in terms of hierarchies, however, this research has outlined a process for organising media types into hierarchies. With this hierarchical structure, it becomes easier to manage a growing list of available media types. The hierarchical structure begins with a generic media type called Media, which is at the top of the tree and is the parent or ancestor of all known media types. The rule for deciding where to place media types in the hierarchy is based on the relationship that exists between the media type to be placed and the parent media type of the node where it will be placed. The condition to be satisfied is that the parent media type must have an 'is a' relationship with the child media type. This means it should be possible (although not encouraged) to use a parent media type in place of a child media type because a child media type has an 'is a' relationship with a parent media type, therefore, it can be said that the child media type 'is a' parent media type. The media selection framework (discussed next) relies on this method of organising media types. This contribution is useful because when media is being selected for use in educational materials, the hierarchical structure effectively narrows the available media options at every stage of the selection process. This means that there is always less to choose from at each stage and therefore a higher likelihood of making a more appropriate media selection (because media types are less likely to be missed). In essence, the choice of media moves from a more generic media type to a more specific media type. The hierarchical media taxonomy is a minor contribution of the research and although it may be used in other contexts, in this research, its main purpose is to support the media section framework which is the major contribution of this research.

11.3.2 The Media Selection Framework

The media selection framework proposes a set of rules for organising and tagging available media types for use in educational materials, developing information identifiers from the available media types, mapping the information identifiers to media types, and selecting media types for the development of educational materials. First, one needs to identify all available media types and organise them into a hierarchical structure using the rules set out by the Hierarchical Media Taxonomy. The media types also have to be assigned to one or more target devices and to a VARK learning model. This could be referred to as a 'tagging' process. Once all media types have been identified and 'tagged', the information presenting attributes and capabilities of the media types are then identified and these are used to create keywords which have been referred to in this research as information identifiers. These information identifiers are then collated and mapped back to the respective media types from which they were created. The mapping also has to record the 'priority' of each media type that is mapped to an information identifier, as this 'priority' information will be used to resolve multimodal selection. During the media selection stage, the user selects a set of information identifiers, and these are used to generate a recommended media type. The recommendation is based on the algorithm described in chapter six of this thesis. If the recommended media type has sub types, the media selection process is repeated on the sub types, using only information identifiers that map to sub types of the recommended media type, until a recommendation that has no sub type is achieved. The media selection process can be tailored to a learning preference and/or a target device(s) using the target device and VARK learning model tags from the tagging stage. This novel media selection framework constitutes the main contribution of this research, and it allows for a methodical selection of media for the development of effective educational materials.

11.3.3 The Media Selection Method

The media selection framework, as discussed in the previous section, sets out the process through which a user can identify a set of media types, organise them into hierarchies (following the rules of the hierarchical media taxonomy), tag the media types, use them to create information identifiers, map the information identifiers back to the media types, and assign priority values to each media mapping. However, the media selection method constitutes the current collection of the tagged media types, the information identifiers, the media mappings, the priority values assigned to the media mappings and the way they are structured. A media selection method is created using the process defined by the media selection framework and a media selection method is modifiable. This means that it is possible that future observation or research may reveal a better combination of tagged media types and their hierarchical structure, information identifiers, identifier-to-media mapping and the priority values assigned to each media mapping. The media selection application, which was developed in chapter eight, holds the data that constitutes the media selection method and was developed using algorithms that conform to the media selection framework. The current combination of tagged media types, information identifiers, mappings and priority settings have been observed to improve learning when used to develop educational materials, thereby constituting a contribution to knowledge on educational multimedia development.

11.3.4 Other contributions

Other contributions to knowledge are that the research has shown that multimedia does improve learning, and this supports other multimedia research findings. Also, the research has shown that tailoring an educational material to a learner's preference can have positive effects on learning. This is an interesting observation although this is still debated by researcher, therefore, more research is needed to investigate this observation and to understand the circumstances under which a learner's might experience improvements in learning when the learning material is tailored to their preferences and the circumstances under which this might not happen.

11.4 Problems encountered

The major problem encountered during the research is the recruitment of participants. It has been a struggle getting people to participate in the research. For example, the survey conducted in chapter four was sent via email to over 600 lecturers but there were only 35 responses (a 5.8% response rate). The difficulty increases when recruiting people to participate in an observed study such as the validity experiment in chapter seven. People occasionally turned down request for participation for various reasons and some began but were unable to complete the study (usually for good reasons), meaning their data had to be discarded.

11.5 Limitations of the research

One limitation of this research is the sample size of the experiments and surveys. It may have been better to have a greater number of participants as that would provide more confidence in the results obtained. Another limitation of the research is that the research did not consider how some combinations of media for the same learning task might affect the multimedia material and its multimedia effect. A good example of this limitation is a situation where an animation and a sentence are recommended for the same learning task. In such situations, the modality theory suggests that it may be better to use animation with speech, rather than text. The speech could be embedded into the animation and presented as one media. Although a careful analysis of the learning tasks can reduce this possibility, it would have been useful to provide the media selection framework and the application (as an internal function) with a strategy for dealing with this.

11.6 Suggestions for future work

Some recommendations for future work include the following:

- The focus of this research has been on the media types that are used in the development of educational materials, their information presenting attributes and capabilities and what kinds of educational concepts are best represented by the media types. As learners' needs differ (for example, accessibility), future research could look at how the varying needs of learners might be addressed during media selection.
- Given that the issue of learning styles is still debated, there should be further study into the effects of tailoring educational multimedia to the learner's preferences. In particular, it is necessary to understand the circumstances under which learning might

be improved when the educational material is tailored to a learner's preference and the circumstances under which learning might not be improved.

- This research was focused on the 'what' (that is, what media type to use) and not the 'how' (how to design that media type effectively). We now know that it is possible to have a methodical approach to media selection, however, future research could focus on a methodical approach to designing the selected media types.

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Appendix 1: Multimedia Design Survey

The aim of this survey is to understand how educators develop educational materials.

You will be asked questions about how you design educational multimedia materials (such as PowerPoint slides for lectures/lessons, web-based learning materials, PDF learning materials, books, educational videos, etc.) and what methods you follow. This should take about 15 minutes to complete. The survey involves no more risk than that which is encountered in daily life (e.g. using a computer or completing a form).

Every information collected will be treated with full confidentiality, will be anonymised and will not be used for any other purpose outside the research. Participation is voluntary and participants reserve the right to withdraw at any time. To do this (or to request additional information about the research, such as the results or outcome), kindly contact the researcher by on **c**higozie.onyekaba@research.staffs.ac.uk.

If you are 18 years of age or older, understand the statements above and freely consent to participate in the study, kindly tick the box below to proceed, otherwise please close the web page.

*Required

Do you consent? *

If you do not consent, kindly close the web page.
Mark only one oval.

- ◯ Yes

All questions are optional

1. To what age group do you belong?
   Mark only one oval.

   - ◯ Below 25
   - ◯ 25 - 34
   - ◯ 35 - 44
   - ◯ 45 - 54
   - ◯ 55 - 64
   - ◯ 65 and above

2. What is your highest educational qualification?
Mark only one oval.

- ( ) Bachelor's Degree
- ( ) Master's Degree
- ( ) Doctorate Degree
- ( ) Other: ______________________

3. How many years teaching experience do you have?

____

4. How many years' experience do you have in designing learning / educational multimedia materials (such as books, presentation slides, videos, etc.)?

____

5. Do you adhere to, or follow (in full or in part) any multimedia design methods or principles when designing educational multimedia materials?
Mark only one oval.

- ( ) Yes *Skip to question 7.*
- ( ) Sometimes *Skip to question 7.*
- ( ) No *Skip to question 10.*

6. What educational multimedia design method(s) do you use?
Please give as much information as you can, including how you apply your chosen method to designing educational material

____

____

____

____

7. Do you ALWAYS follow this (or any other) educational multimedia design method?

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Other ______________________

8. Based on your observation, does your described educational multimedia design method(s) lead to better learning experiences for your learners?

Mark only one oval.

- ( ) Yes
- ( ) Sometimes
- ( ) No
- ( ) Other ______________________

9. How do you design educational multimedia materials? Please give as much information as possible.

These include powerpoint slides, PDF materials, books, videos, etc.

____
____
____
____

10. How do you validate the media types (images, animations, audio, video, etc.) you have used, that is, how do you ascertain you have chosen the right media type for the intended purpose?

Please give as much information as possible.

____
____
____
____

11. Do you agree that following an educational multimedia design method could lead to improved learning experiences?

Mark only one oval.

- ⬭ Agree
- ⬭ Neutral / Unsure
- ⬭ Disagree

12. Please give reasons for your answer in the above question

Why do you agree (or disagree) that following an educational multimedia design method could lead to improved learning experiences?

____

13. What do you think is good (or bad) about using an educational multimedia design method?

What might be the advantages (or disadvantages) of using a multimedia design method?

Powered by Google Forms

Appendix 2: Research Consent Form (V)

Validity Experiment - Consent Form

We are conducting a study to assess the impact of different media types on learning. In this study, participants will be asked to perform some learning tasks, after which, they will be asked to answer some questions. This should take about 30 minutes to complete. The study involves no more than the same level of risk encountered in daily life (e.g. using a computer or completing a form).

Every information collected will be treated with full confidentiality, will be anonymised and will not be used for any other purpose outside the research. Participation is voluntary and participants reserve the right to withdraw at any time. To do this (or to request additional information about the research, such as the results or outcome), the participant will have to contact the researcher by email on chigozie.onyekaba@research.staffs.ac.uk.

If you are 18 years of age or older, understand the statements above and freely consent to participate in the study, kindly write your name and sign below.

Name: ____

Signature: ____________________________ Date: __________________________

Appendix 3: Profile (Validity Experiment)

In order to properly analyse the study data, we need a few details. Kindly fill out the information in this form. Thank you.

Name: ____

Gender: ◯ Male ◯ Female

Age: ____

Programme: ____

Faculty:

- ◯ Computing, Engineering and Sciences
- ◯ Health Sciences
- ◯ Arts and Creative Technologies
- ◯ Business, Education and Law

Level of Study

- ◯ Undergraduate
- ◯ Postgraduate

Email: ____

Mobile (SMS): ____

Contact Preference: ◯ Email ◯ SMS ◯ Both

Appendix 4: Validity Experiment Procedure

1. Recruit the participant, obtain consent and ask the participant to complete the profile questionnaire.

2. All participants would be assigned to one of two groups of equal characteristics (using profile information), one experimental group and one control group.

3. On the test day, the procedure will be read out to the participant (see below).

4. The participant will be asked to perform some learning tasks on a PC or laptop.

5. After the learning task, the participant will be given a quiz, aimed at measuring learning effectiveness of the educational material.

6. End of experiment.

Script to be read out to the participant:

We are carrying out an experiment to measure the effect of different multimedia designs on learning. In this experiment, you would be presented with a multimedia material which you would be asked to study for 20 minutes. You would then be presented with a timed short quiz.

Please answer the questions based solely on what you have learned from the multimedia material. Please remember that this experiment does not aim to assess your learning abilities, rather, it is designed to measure the effectiveness of the learning material design.

The entire exercise is expected to take no more than 30 minutes. Thank you.

Appendix 5: Profile (Usability and Reliability)

In order to properly analyse the study data, we need a few details. Kindly fill out the information in this form. Thank you.

Name: ____

Gender: ◯ Male ◯ Female

Age: ____

Do you have teaching experience?

◯ Yes (How many years?) ______________________________

◯ No

Do you have experience in designing learning / educational materials?

◯ Yes (How many years?) ______________________________

◯ No

Email: ____

Mobile (SMS): ____

Contact Preference: ◯ Email ◯ SMS ◯ Both

Appendix 6: Research Consent Form (U & R)

Usability & Reliability Experiment - Consent Form

We are conducting a study to assess the reliability and ease of use of a media selection framework for educational multimedia design. In this study, participants will be taught how to use a tool to select media for educational design, after which, they will be asked to map educational concepts to media types. This should take about 30 minutes to complete. The study involves no more than the same level of risk encountered in daily life (e.g. using a computer or completing a form).

Every information collected will be treated with full confidentiality, will be anonymised and will not be used for any other purpose outside the research. Participation is voluntary and participants reserve the right to withdraw at any time. To do this (or to request additional information about the research, such as the results or outcome), the participant will have to contact the researcher by email on chigozie.onyekaba@research.staffs.ac.uk.

If you are 18 years of age or older, understand the statements above and freely consent to participate in the study, kindly write your name and sign below.

Name: ____

Signature: ________________________________ Date: ____________________________

Appendix 7: Experiment Procedure (U & R)

Usability & Reliability Experiment Procedure

1. Recruit the participant, obtain consent and ask consenting participant to complete profile questionnaire.

2. On the test day, a demonstration of how to use the media selection framework will be shown to the participant. The participant will be allowed to ask further questions about how to use the media selection framework (and tool) it at this stage. The idea is to ensure the participant fully understands how to use the selection tool.

3. The participant will subsequently be provided with a list of learning concepts and will be asked to map each concept to a media type. The participant may not ask questions about how to use the framework once they begin the concept to media mapping task.

4. After the mapping task, the participant will be asked to complete a questionnaire about his/her perception of the ease of use of the framework. A modified version of Lund's USE questionnaire would be used.

5. The participant would also complete a NASA Task Load Index questionnaire.

6. End of experiment.

Appendix 8: Case Study Materials

Introduction to objects and classes

Page 1

What is an object?

- An object is defined as anything that can be seen and touched.
- Objects are key to understanding the object-oriented programming paradigm.
- An example of an object is a car.

Page 2

A car is an object

Page 3

Object characteristics

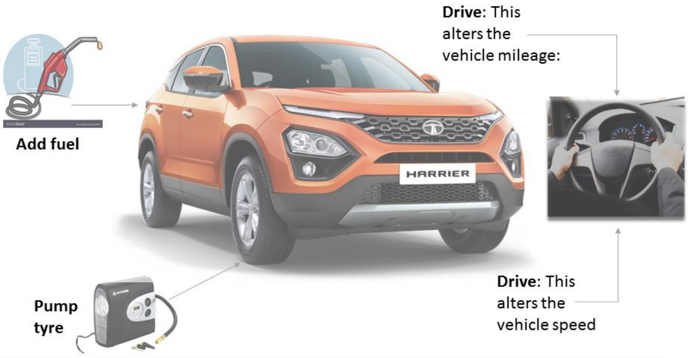
- Objects have two characteristics
  - State (attributes, situation, condition, etc).
  - Behaviour (actions, functions, things the object can do).

Car states and behaviours

- Car states include current speed, mileage, tyre pressure, fuel level, etc.
- Car behaviours include drive, pump up tyres, add fuel, etc.

Car states

Car behaviours



Parameters

- Notice that some behaviours require extra information. For example…

- **Add fuel:** How much fuel?
- **Drive:** At what speed?
- **Pump tyre:** To what pressure?

- Such extra information are referred to as **parameters**.

Software objects

- A software object is a software bundle of related state and behaviour.

- The states and behaviours of an object are collectively known as its members.

Terminologies

- A state is also known as an attribute or a **field**.
- A behaviour is also known as a **method**.
- The thing(s) they need to exhibit their behaviour is known as **parameters**.

Class

- A class is the blueprint from which objects are created.
- To create a software object, programmers have to design/write a class first.
- It is from this class that the computer creates software objects which contain the state values.

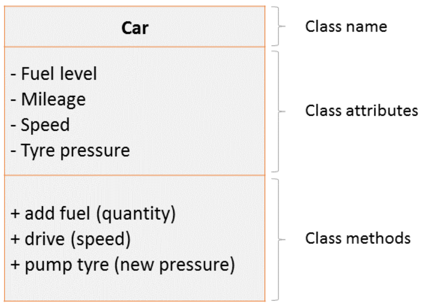
Classes and Objects

- Using the car analogy, there is only one car design specification (the blueprint) and many cars are produced from that design.
- The cars produced from that design document will have different states, for example, different mileages, fuel levels, tyre pressures, etc.

Class diagrams

- Class diagrams are used to describe classes.
- It is a rectangle split into three sections: -
  - Top section contains the name of the class
  - The middle section contains the attributes
  - The lower section contains the methods.

UML Class diagram structure



Summary

- You've just learned about
- Physical objects
- Object characteristics
  - State
  - Behaviour
- Software objects
- Classes
- Class diagram

The laws of demand and supply

Page 1

The law of demand

- The law of demand states that an increase in the price of a product results in a decrease in the quantity demanded.
- This law assumes that all other factors remain unchanged.

Page 2

An example

- Consider the demand for a DVD. As the price of a DVD increases, less people buy it.
- The table on the next slide/page shows the relationship between the price of the DVD and the quantity demanded.
- The table is called a demand schedule.

Page 3

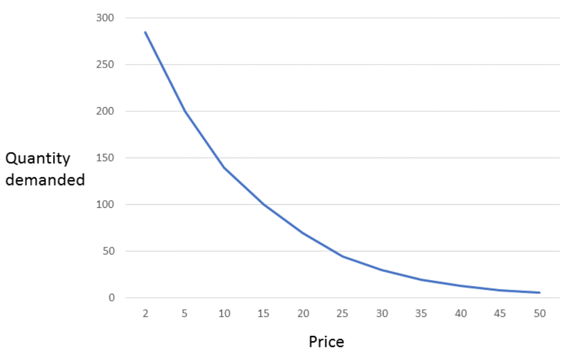
Relationship between price and quantity demanded

Price	Quantity Demanded
2	285
5	200
10	140
15	100
20	70
25	45
30	30
35	20
40	13
45	8
50	6

DVD demand

- The line chart on the next slide/page also shows the relationship between the price of the DVD and the quantity demanded.
- This is called a demand curve.

Demand curve



Law of supply

- The law of supply states that an increase in the price of a product results in an increase in the quantity supplied.
- The law assumes that all other factors remain constant.

An example

- Consider the same DVD case as an example.
- As the price of a DVD increases in the market, DVD producers will want to offer more of it for sale, hence an increase in the supply.

DVD supply schedule

- The table on the next slide/page shows the relationship between the price of the DVD and the quantity supplied.
- This is called a supply schedule.

Relationship between price and quantity supplied

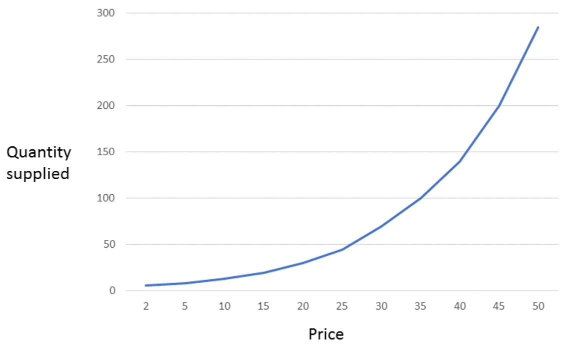
Price	Quantity Supplied
2	6
5	8
10	13
15	20
20	30
25	45
30	70
35	100
40	140
45	200
50	285

DVD supply

- The line chart on the next slide/page also shows the relationship between the price of the DVD and the quantity supplied.

- This is called a supply curve.

Supply curve



Summary

- You've just learned about
  - The law of demand
  - The demand schedule and curve
  - The law of supply
  - The supply schedule and curve

Appendix 9: Application Screenshots

Media Selection Application

Select Media...

Identifier Management

Media Management

Target Device Management

1. Please select your VARK preferences (or leave blank if no preference)

Select	VARK Modality
☑	Visual
☐	Aural
☐	Read-Write
☑	Kinaesthetic

2. Now select the device(s) the recommended media is intended for (leave blank for all devices)

Select	Target
☐	Print
☑	Screen
☐	Audio Players

3. Now select the required identifiers...

Select	Identifier Name	Description (click a description to view more)
☐	Code	This identifier may be selected in situations wher...
☐	Data	This identifier may be selected where the aim is t...
☐	Maths	This identifier may be select when teaching about ...
☑	Model	Sometimes, learning concepts cannot be concisely p...
☑	Motion	This identifier may be selected for the teaching o...
☑	Object	This identifier may be selected in situations wher...
☐	Reality	This identifier may be selected in situations wher...
☐	Requirements	This identifier may be selected where the teaching...
☐	Sound	This identifier may be used for concepts where lea...
☐	Message	This identifier may be selected for teaching conce...
☐	Static	This identifier may be selected when teaching abou...
☑	Demonstration	This identifier may be selected when learning conc...

Click a description in the table to view more...

Media selection results...

Recommendation	Media Name	Subtype?
Recommended	Animated Diagram	SELECT SUBTYPES
Alternative	Video	None
Alternative	Diagram	SELECT SUBTYPES

Add New Media Type

[Media Management]

[Home Page]

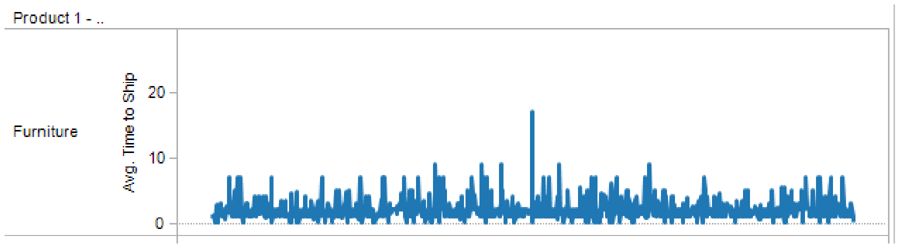
Media Name:	
Parent Media:	[No Parent]
Modality:	Visual
Description	
Target	Print Screen Audio Players
Sample URL:	
	Add Media

View/Edit Media Type

[View Media Types]()

[Home Page]()

Media Name:	Chart
Parent Media:	Image (Parent: null)
Modality:	Visual
Description	A chart is an image media type that is used to present a visual representation of data or anything that is data related. Examples are pie charts, histograms, line charts, scatterplots, etc
Target	☑ Print ☑ Screen ☐ Audio Players
Sample URL:	Chart.png
☐ Edit?	Save Media



View/Edit Identifier (Demonstration)

This form edits only the name and description

To edit the media mapping, please click here

View Identifiers

Home Page

Identifier Name:	Demonstration
Description	This identifier may be selected when learning concepts involve an activity or process that needs to be exhibited or demonstrated. This is usually the case when there is a need for an individual to physical show how something is done or how something works. Example: An example of when this identifier may be used is when there is a need to teach about to weld a metal. Demonstrating the process to learners makes it much easier to learn than when such is described through other non-demonstrated means
Media Mapping	Video (Parent: Null) Animated Diagram (Parent: Animation) Animated Chart (Parent: Animation)
☐ Edit?	Update Identifier