

POTENTIAL RELEVANCE OF NEUROSCIENCE TO GUIDE CONSUMPTION OF MULTIMEDIA TECHNOLOGIES TOWARDS ENHANCING LEARNING

A DISSERTATION PRESENTED TO THE

DEPARTMENT OF INFORMATION SYSTEMS



UNIVERSITY OF CAPETOWN

By

EDWIN WANJOGU

Supervised by: Dr. Sumarie Roodt

AUGUST 2014

In partial fulfilment of the requirements for the Masters in Information Systems

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

**POTENTIAL RELEVANCE OF NEUROSCIENCE TO GUIDE
CONSUMPTION OF MULTIMEDIA TECHNOLOGIES TOWARDS
ENHANCING LEARNING**

PLAGIARISM DECLARATION

I know that plagiarism is wrong. Plagiarism is to use another's work and pretend that it is one's own.

I have used the American Psychological Association (APA) convention for citation and referencing throughout the dissertation. Each contribution to and quotation in this dissertation

"Alignment of Human Competencies with Mobile Technology and Business Strategy in Women-led SMEs" from the work(s) of other people has/have been attributed and has been cited and referenced.

This dissertation "Alignment of Human Competencies with Mobile Technology and Business Strategy in Women-led SMEs" is my own work.

I have not allowed and will not allow anyone to copy my work with the intention of passing it off as his or her own work.

I acknowledge that copying someone else's dissertation, or part of it, is wrong and declare that this is my own work.

Signature

Signed by candidate

Signature Removed

Date: 1st August 2015

Full Name of Student: Wanjogu Edwin

Student Number: WNJEDW001

Abstract

In the wake of rapidly progressing technology, educational institutions are searching for more innovative uses of educational technologies to teach the new kind of students who are entering into these institutions. The Net Generation (NG), are believed to have grown up surrounded by technology and this poses a challenge of understanding how well-designed technology improvements can enhance a student's educational experience. The main reason as to incorporating technology with education is without a doubt to improve a student's engagement and learning.

There is increasing interest in the application of cognitive neuroscience in educational practice to advice on how to improve the learning content to have a more positive impact on the NG with an understanding of the brain. Research does show that if technology is not weaned correctly, can have negative effects and addictive behaviours emerge such as craving, concealing, and lying. There is no link, to the author's knowledge, between these scientific findings of neuroscience and advising institutions on changes and implementations necessary to the learning material. This study sets out to link the three; using Piaget's Theory of Cognitive Development as the guide of the different categories of the NG and a detailed literature review of other theories of this phenomenon, the three elements (Learning, Technology and Neuroscience) were investigated.

Using secondary analysis the researcher was able to analyse different data sets of the different age groups as stipulated by Piaget's Theory. Each study sought to investigate the NG with different learning MTs and the effects it had on them. The results were ran through different statistical tests revealing positive links of the three aforementioned elements. The findings asserted that students learning with these multimedia obtained significantly greater learning achievement in comparison to those who were not. Not only so, but these same students were also more motivated by using technology in the classroom for learning and exhibited increased functional connectivity during their engagement.

Finally, the three elements were linked by developing a life-stage technology consumption model that will be capable of guiding instructors, NG and the consumers of various MTs.

ACKNOWLEDGEMENTS

My deepest gratitude to the following people:

To Prof Sumarie Roodt, for her honest but constructive criticism throughout my research and teaching me how to maximize on my opportunities.

To my family Jane, Sharon and Brian for their unwavering support and doses of encouragement through the challenging times.

To my friends and brothers who constantly reminded me of my goals and dreams.

A sincere thank you to my colleagues at the IS department who took time to instruct and counsel me in my research.

Contents

CHAPTER 1: INTRODUCTION	11
1.1 Introduction and Background	11
1.2 THE RESEARCH QUESTIONS AND OBJECTIVES	15
1.3 MOTIVATION FOR THIS RESEARCH	16
1.4 LIMITATIONS OF THE RESEARCH.....	17
1.5 AN OVERVIEW OF THE DISSERTATION.....	18
2.0 LITERATURE REVIEW	20
2.1 Introduction	20
2.2 Kolb’s Experiential Learning Theory.....	23
2.3 Cognitive Theory of Multimedia Learning	28
2.4 The Net Generation (NG)	33
2.4.1 Claims about the NG	33
2.4.2 Criticisms of the NG	34
2.4.3 Skillset and Use of Technology amongst the NG	34
2.4.4 Learning Style Preferences of the NG	35
2.4.5 Student Engagement.....	37
2.5 Technology in Learning	39
2.5.1 Access to Technology.....	39
2.6 Technology Enhanced Learning (TEL)	40
2.6.1 Factors Encouraging TEL	41
2.7 Technology Acceptance	44
2.7.1 Barriers to Implementation of Technology.....	45
2.8 Bridging TEL and Cognitive Neuroscience	48
2.8.1 The Basics of Cognitive Neuroscience.....	48
2.8.2 The Brain Structure	48
2.8.3 The Engaged Brain in Learning.....	50
2.8.4 Methods and Techniques in Brain Data Collection.....	51
2.9 Piaget’s Theory of Cognitive Development.....	55
2.10 Summary of the Literature review	58
3.0 RESEARCH DESIGN	60
3.1 Research Paradigm and Epistemology.....	60
3.2 Research Methodology	62
3.3 Research Strategy	62
3.3.1 Understanding Secondary Analysis.....	62
3.3.2 Strengths of Secondary Analysis.....	64

3.3.3 Selecting the Right Data Sets	65
3.4 Purpose of Research	66
3.5 RESEARCH APPROACH	67
3.6 RESEARCH INSTRUMENT.....	68
3.6.1 Data Collection.....	68
3.6.2 Outcomes of the Searches	72
3.6.4 Timeline.....	76
3.6.5 Ethics and Confidentiality	76
3.7 Summary of the Chapter.....	78
4.0 ANALYSIS, FINDINGS AND DISCUSSIONS.....	81
4.1 Introduction	81
4.3 Data Analysis within the PTC D Stages.....	84
4.4 ANALYSIS ONE	85
4.4.1 The study.....	85
4.4.2 Stated Procedure	85
4.4.3 Ethical Considerations.....	86
4.4.4 Demographics of the Participants.....	86
4.4.5 Coding and Reliability.....	87
4.4.6 Hypothesis.....	89
4.4.7 Results of the Analysis	89
4.5 ANALYSIS TWO	91
4.5.1 Stated Procedure	91
4.5.3 Demographics of the Participants.....	92
4.5.4 Reliability and Validity.....	92
4.5.5 Data Analysis and Discussion	93
4.6 ANALYSIS THREE	95
4.6.1 Data Set One	95
4.6.2 The Procedure.....	95
4.6.3 Ethical Considerations.....	96
4.6.4 Demographics of the Participants.....	96
4.6.5 Reliability and Validity.....	97
4.6.6 Hypothesis.....	97
4.6.7 Results and Discussion	98
4.6.7 Data Set Two	100
4.7 Chapter Summary	104
CHAPTER 5: LIFE STAGE TECHNOLOGY MODEL	107

5.1 Introduction	107
5.2 The Contributors	107
5.2.1 Piaget’s Theory of Cognitive Development (PTCD).....	107
5.2.3 ELT and CTML.....	108
5.2.4 The Secondary Analysis.....	108
5.2.5 The Nedunology Model.....	108
5.3 Chapter Summary	110
CHAPTER 6: CONCLUSION AND RECOMMENDATIONS	112
6.1 Conclusion.....	112
6.2 Future Research	113
6.3 Final Remarks	114
REFERENCES.....	116
Appendix A: Email Authentication for Database Access	127
Appendix B: Brain Scans Used in Analysis Two	128
Appendix C: Brain Scans Used in Analysis Three, Data Set Two	129
Appendix D: Ethics Approval Form	130
Commerce Faculty Ethics in Research Committee	130
1. PROJECT DETAILS	130
2. PARTICIPANTS	132
3. ORGANISATIONAL PERMISSION.....	133
4. INFORMED CONSENT	133
5. CONFIDENTIALITY OF DATA	135
6. RISK TO PARTICIPANTS.....	135
For Ethics committee representative only.....	140
For Ethics committee chairperson only	140

List of Figures

Figure 1: NG's Preferred Learning Style.....	26
Figure 2: Cognitive Theory of Multimedia Learning.....	30
Figure 3: Technology preference of NG students in Classrooms.....	38
Figure 4: Aims of TEL.....	41
Figure 5: Barriers to the development of TEL.....	45
Figure 6: Brain Staining Techniques.....	51
Figure 7: Brain Mapping Tools.....	54
Figure 8: Stages of Cognitive Development.....	56
Figure 9: AND Boolean Return.....	69
Figure 10: OR Boolean Return.....	70
Figure 11: Outcome of Searches.....	72
Figure 12: Areas of Interest.....	102
Figure 13: The Nedunology Model.....	110

List of Tables

Table 1: ELT's Learning Cycle.....	23
Table 2: Cognitive Assumptions.....	28
Table 3: Cognitive Processes.....	29
Table 4: Driving factors of TEL.....	42
Table 5: Strengths and Weaknesses of Secondary Analysis.....	65
Table 6: Different Types of Secondary Analysis.....	66
Table 7: Summary of Research Design.....	79
Table 8: Order of Secondary Analysis.....	84
Table 9: Gender Distribution.....	86
Table 10: Mean Age (Days).....	86
Table 11: Race Categories.....	87
Table 12: Exclusion Criteria.....	88
Table 13: Split Half Analysis Results.....	88
Table 14: Gender Distribution.....	92
Table 15: Mean Age.....	92
Table 16: Age Distribution.....	96
Table 17: Mean Age (Years).....	97
Table 18: Cronbach's Alpha.....	97
Table 19: Difference T- Test Results.....	98

CHAPTER 1

INTRODUCTION

CHAPTER 1: INTRODUCTION

1.1 Introduction and Background

Learning is not a new concept, it has been around for thousands of years as the cornerstone and foundation of intelligence and livelihood of the human race (Dror, 2013). On the other hand, the use of technology in learning is a fairly new endeavour. A few years back, one could only place about a handful of people who have experienced technological applications in the domain of learning (Dror, 2008). As more innovations were developed, learning and technology are no longer considered as didactic rivals (Hu, 2008). With its development, technology has become an integral part of modern education, managing to penetrate all aspects of learning (Hu et al., 2008). Dror (2013) claims that it is not an easy task to define which technologies are purely for learning and choosing to list them down would have to include the most rudimentary of them all. These include electronic blackboards and software for presenting information such as PowerPoint. And yet, most of the learning is informal; the internet is a technology that has completely changed how we view, access, and share information which also plays a role in learning (Li et al., 2015; Dror, 2013).

Technology Enhanced Learning (TEL) seeks to enhance the student learning experience whilst sustaining student engagement and enhancing retention (Trepule, 2015). Too often however, learning is mostly associated with only the acquiring of information and the most fundamental aspect of it is forgotten; retention. There is a need to consider what TEL can offer, not just the acquiring of information but mainly its long term retention. On a foundation level, it is the students' cognitive system that acquires the information, retains it and uses it later when need arises (Dror, 2013).

For many years, researchers have focused on 'bridging the gap' that is believed to be between education and neuroscience and various attempts are constantly being drawn towards this (Goswami, 2006; Hruby, 2012; Edelenbosch, 2015). Sigman et al. (2014) also iterated that it is prime time for this gap to be filled and the two stems to work in concert towards enhancing learning. Bridging-the-gap does portray an image of a missing single entity that needs to be placed in between the two, however, there are trends all over the world looking to do that and most of which are commercial

(Edelenbosch, 2015). The researcher argues that it is important to focus on gaining deeper insight in practical approaches within the different fields that can be applied in a real classroom setting away from the scientific rigor. It is therefore necessary for educators and instructors to understand the human cognitive mechanisms that work together during learning and much more when involving TEL (Bavelier & Davidson, 2013).

The development of multimedia and digital technologies such as the World Wide Web and personal computers have stemmed in a new generation of technically literate individuals called the Net Generation (NG) and they are said to have been born between 1982 and 2003 (Berk, 2009b; Prensky, 2001). Out of the technical literacy of these individuals, their learning styles are different from their predecessors and these related technologies have had a major influence on NGs' culture and development (Berk, 2009b). A lot of NG students have never known a world without personal computers, the internet, highly interactive video games and cellular phones. TEL is already a force that is in motion and gaining more momentum every year and the use of technologies in education has been recommended as a tool to engage NG students (Roodt & De Villiers, 2011). A major argument for why it is imperative to investigate multimedia learning is that a large volume of studies have conclusively shown positive outcomes from teaching with both text and pictures (Schweppe et al., 2015). This renowned verdict is known as the multimedia effect (Mayer, 2009). Mayer (2014) shows that presenting with a picture benefits memory retrieval and also not only does it improve performance, but it provides long and stable memory benefits (Schweppe et al., 2015). In contrast, from the increased inactive time children are spending with technology and reduced time in playing outside, links are being drawn between overuse of technology and a delay in the NG's achievement of sensory (such as taste, touch, vision, hearing, and smell which develop through movement and exploration) and motor milestones (the ability to use large muscles for movements such as crawling, or walking) (Rowan, 2010) and reduced academic performance (Gentile, 2012). The overuse of technology has also been associated with sleep difficulties and increased anxiety, depression and isolation in some cases (Farber et al., 2012). Seemingly, technologies that were initially developed for the purpose of

enhancing cognitive abilities, may lead to no effects or, worse, may lead to unanticipated negative effects (Owen et al., 2010 and Zimmerman et al., 2007). Therefore, the researcher intends that this research will be able to advise in effective use by utilizing informed and intentional design of instructional technologies that engage the students intellectually and academically.

This study has followed the blueprints of Piaget's Theory of Cognitive Development (Piaget, 1976) to help map the life stages at which the brain is most receptive to preferred learning styles. The theory was believed that the human brain was fully grown by the end of early childhood (Mann, 1984) but revisions of Piaget's theory of cognitive development bring to light more comprehensive conclusions as to the building blocks of the brain. These building blocks that happen at every life stage and are vital to the developments of executive functions (an umbrella term for the management (regulation, control) of cognitive processes, including working memory, reasoning, task flexibility, and problem solving as well as planning and execution)(Carew & Magsamen, 2010). Understanding these building blocks and matching them to the correct type of TEL is what this study aims to achieve in order to make learning much more effective. Neuro-Education then becomes a blend of both education and neuroscience to ultimately map out a clearer understanding of how learning occurs and in turn create more effective teaching techniques. Extensive research has been conducted to gauge the levels of learning retention and the brain, engagement of NG students in various learning technologies (Bavelier, Green & Dye, 2010). Furthermore, literature on real time images of an engaged brain reiterate the physical link of these MTs and improvement of executive functions of the NG (Gray, Chaban, Martinussen, Goldberg, Gotlieb, Kronitz, Hockenberry & Tannock, 2012). To this point, the researcher was unable to find any literature that has developed a working model that links the age of the NG to appropriate MT.

Ultimately, this study seeks to heed the call of Sliwka & Yee (2014), to create more engaged NG learners. Learners who give "serious emotional and cognitive investment in learning, using higher-order thinking skills (such as analysis and evaluation) to increase understanding, solve complex problems, or construct new knowledge" (Sliwka & Yee, 2014:2).

The next section presents the research questions and research objectives of this study.

1.2 THE RESEARCH QUESTIONS AND OBJECTIVES

The primary research question for this study is:

What kind of multimedia technologies should be used at different cognitive life stages to enhance learning?

The sub research questions are:

1. *What kinds of animations or illustrations have higher capabilities in delivery of information?*
2. *How does neuro-education advice in the effective use of multimedia technologies?*

The primary objective of this study is as follows:

To develop a life-stage multimedia technology model that appropriates which technology is most effective at what age group.

The secondary objectives are:

1. *To investigate the significance of TEL compared to the traditional method of teaching*
2. *To link neuroscience, technology and education to work practically together in effective classroom teaching*

1.3 MOTIVATION FOR THIS RESEARCH

Primarily, this research aims to enhance learning by identifying what type of multimedia technology (MT) is most effective in each different life stage as defined by Piaget's Theory of Cognitive Development. The researchers approach is to move beyond the regular view of building a bridge that simulates a movement of knowledge from point A to point B. In its place, leverage the milestones achieved in each field by integrating the knowledge of both disciplines into more applicable and recognizable practices that both neuroscientists and educators have come to agree on.

Technology has become so intertwined in our daily lives it is somewhat hard to re-enact a world without it. This translates to technology becoming a part of our cognitive processes as well and in turn affecting our very nature (Novak & Tassell, 2015). It for this reason also that the researcher sees the need to greatly analyse what TEL can offer, not limiting to the acquisition of information but also what role it can play in long term memory retention. Extant literature confirms that various aspects of TEL have been researched by previous information systems teams who were looking to examine the learning outcomes and the effectiveness of the methods used. A lot of literature shows equivocal empirical results, an example being Hu et al. (2007) who highlights that there are no significant differences in learning performance between the old tactic of face to face learning and the use of TEL. Whereas other studies do show significant improvements whilst engaging with TEL (Mayer, 2009).

By adopting the use of TEL designs in the classrooms and including different brain scans of the NG engaging in these various MTs, this study becomes relatively more comprehensive in evaluation of these designs. Thereafter, it allows for an exploration of plausible relationships between the learning styles and the observed effectiveness and outcomes of TEL. Through this research, understanding the extent to which TEL can be weaned to enhance learning allows for instructors to create more engaging work for the NG student. These students would then feel that this type of work is worthy of their time and attention, relevant and rooted in their current world in which they live in (Sliwka & Yee, 2014).

1.4 LIMITATIONS OF THE RESEARCH

Due to the cross-sectional nature of this study, gathering participants from different age groups, receiving ethical approval for all and finally gathering neuro-images of their engaged brains would go beyond the deadlines of the stipulated research timeline.

To carry out neuro imaging techniques on participants is both expensive and time consuming. The neuro imaging technology is not at the researcher's disposal and other possible avenues are costly or prioritised for health science students. However, the researcher does recognize that there are more affordable devices that have recently been developed particularly because of reasons such as this but access to these devices is still a major challenge.

Secondary analysis prevents the researcher from collecting additional data that would aid in direct answering of the research questions. There were instances of insufficient documentation of the original data collection procedures, making interpretation and analysis of the results impossible. This resulted in more time used in searching for alternative data sets for use.

1.5 AN OVERVIEW OF THE DISSERTATION

The aim of this chapter was to introduce the research study at hand. It provided the background to the research problem and justifications as to why the researcher chose this particular research problem.

The following chapter (Chapter 2) is a review of the literature review which covers the key themes of this study: Learning; TEL; and Neuro-Education. Thereafter, gaps that were identified within the review are highlighted and the intentions that this study has of filling those mentioned gaps.

Chapter 3

- Delves into the research design, explaining all aspects starting with the philosophical stance taken, the research methodologies and approach, research strategy as well as the data collection and analysis techniques used.

Chapter 4

- Documents the results and findings from the analysis of the data and discussions that follow each set of results

Chapter 5

- Consolidates the findings from the data analysis and with them, the proposed life stage technology model is developed

Chapter 6

- Provides the conclusion to this dissertation, including recommendations for further research

CHAPTER 2

LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 Introduction

Philosophers and psychologists have sought to understand the nature of learning, how and where it occurs, what the optimum conditions are and how one person can influence the learning of another person through teaching and similar endeavours. In relation to progress of people, learning is one of the most important activities in which humans engage in and it is at the very core of the educational process (Shuell, 2013). Various definitions and theories of learning have been suggested by scholars throughout the years; some have focused on the attainment of skills such as learning to read, write and type (Anderson, 1981; Bryan & Harter, 1897; LaBerge & Samuels, 1974; NRC 2000). Others have based their research on learning with understanding and its effects on graphic formation and transferal (Judd, 1908; Wertheimer, 1959; Anderson & Pearson, 1984; NRC, 2000). Whilst others still did their research on the development of new ideas through mingling with different people and through daily life practices. After reading through a manifold of the learning literature, there are some principal constants that seem to stand out and have been brought to light by more recent studies. Delivery of knowledge from one party to another is simply what Orr (2009) believes learning to be. The way learning occurs is as important as the content of the course (Orr, 2009), there has to be an equilibrium from which students can find balance and acquire the new information being passed onto them. At first glance, learning involves a permanent change of knowledge often built on existing constructs that allows the individual to amplify or alter what they already know (Kimble 1961). From then on, it ceases to be an idea limited to information sharing alone but a major consideration to a cognitive process that takes place simultaneously. Studies on learning and cognition have come a long way; the study of Lagemann (2002) shows that the field of education has a troubled history as a scientific discipline and later into this section, the researcher will discuss on the importance of cognition to learning. In the field of social sciences, learning usually takes the form of communication between teacher and student with a transfer of information between two or more parties. According to the traditional transmission

approaches, the learner should acquire facts and concepts, by repetitive mnemonic techniques in a systematic fashion (Ravitz et al., 2000). This exercise is mainly aimed at making it easier for the student to remember what is being taught (or repeated) and usually doesn't result in long-term learning of the material. What this old way of teaching failed to understand is that, from a biological point of view, learning and education are closely related to brain development. This is because the brain is adaptable and open to stimuli from the environment one is in (Koizumi, 2004). Consequently making learning a process from which the brain reacts and responds to stimuli. Learning then in effect happens when neuronal connections are made in reaction to the same stimuli and these neurons act as information-processing circuits and provide information storage (Carew & Magsamen, 2010).

The researcher then takes the belief that learning is a cognitive process that implicates numerous abilities involving several cognitive and affective processes such as attention, memory, motivation, emotionality and communications (Goswami, 2006). Undoubtedly, through the rapid strides made by cognitive neuroscience, learning and teaching have been proven to be intricately intertwined with brain function (Leong & Goswami, 2014) and yet for many years, studies conducted in neuroscience and education have been done far part, in silos. As a reaction to this, educational practise has undergone some strong criticisms over the past few decades, with teaching methods being referred to as poorly fit to the dynamics of human cognition (Jörg et al., 2007). The insistence carried throughout most of these literature is not that teachers should not teach (Biesta, 2012), but to make the content and learning material more student-centred so as to cater to the new type of student that are now entering into the educational institutions, The NG.

In this age of information as described by Prensky (2001), NG students, which is the term used to describe the generation born between 1982 and 2003 (Berk, 2009b). For these young people having grown up with computers and the internet has caused a shift in their learning approach. Immersion in this technology-rich culture is said to influence the skills and interests of the NG (NG) in ways significant for education (Oblinger & Oblinger, 2010). It is asserted, for example, that NG students learn differently compared with past generations of students (Pruet, Ang & Farzin, 2014).

They are held to be active experiential learners, proficient in multitasking, and dependent on communication technologies for accessing information and for interacting with others. The NG have to adapt and are rarely taught how to manage large volumes of information in a relatively short time; switching from various teaching styles, to different technologies that are made available to them that come with their own variety of teachers, and finally if successful, assemble all of those into their own way of learning that suits them best (Jones et al., 2010). Mayer (2004) recommends instructional guidance rather than pure discovery, involving methods of instruction that involve cognitive activity rather than behavioural activity and curricular focus rather than unstructured exploration. This goes to show that the NG student should be given room to adapt and integrate a learning style and the teacher should then use this very style to effectively relay knowledge. Constructivism argues that humans generate knowledge and meaning from an interaction between their experiences and their ideas; Ideas that are developed well around the learning environment created by choice style of learning (Piaget, 1976).

The concept of learning styles describes individual differences in learning based on the learner's preference for employing different techniques for acquiring new knowledge (Kolb & Kolb, 2005). The NG students have proven to learn best from experiences that involve a balance of technology and the technical know-how of the instructor in that particular content they are learning from (Oblinger & Oblinger, 2010).

A more detailed look into the NG will be discussed later in this section, however, the next section looks into different theories of learning; Kolb's Experiential Learning Theory (ELT) and Cognitive Theory of Multimedia Learning (CTML). These theories that will be used as the viewing lens to better understand learning and more so how applicable it is to the NG in the current state of the learning institutions.

2.2 Kolb's Experiential Learning Theory

Experiential Learning Theory (ELT) draws on the work of prominent 20th century scholars who gave experience a central role in their theories of human learning and development. From therein, a holistic model of the experiential learning process and a multi-linear model of adult development was developed by David Kolb. Kolb published his learning styles model in 1984 and gave rise to related terms such as Kolb's ELT. Kolb's learning theory sets out four distinct learning styles of which will be discussed later in this section.

Kolb (2005) suggests that for a complete learning experience, students must go through all out four distinct learning phases: Concrete Experience (CE), Reflective observation (RO), Abstract Conceptualization (AC) and Active Experimentation (AE). These four stages of the learning cycle are described in Table 1 below (Levy, 2011):

Stage	Description
Concrete Experience	Where the learner is actively experiencing an activity
Reflective Observation	Where the learner is consciously reflecting back on that experience
Abstract Conceptualization	The learner is being presented with or trying to conceptualize a theory
Active Experimentation	The learner at this stage takes an active form - experimenting with influencing or changing situations

Table 1: ELT's Learning Cycle

Not only do these four stages allow students to comprehensively investigate a topic through different activities and views, they also allow for the accommodation of different learning styles (Abdullah, Tricia & Mahdi, 2014). According to Kolb (1984), knowledge results from the interaction between theory and experience and learning can commence at any of the four stages. To support the claims of Oblinger & Oblinger (2010), Lucu & Marin (2014) also regard the NG to be more of experiential learners and they assert in order to understand how to enhance their learning styles, a grasp of their dominant styles is a necessity. The following is a summary of the four learning

styles based on the earlier mentioned stages of learning and is reinforced with both research and clinical observations as studied by Kolb (2005):

A diverging Learning Style - The style is labelled "diverging" because a person with it performs better in situations that call for generation of ideas, such as a "brainstorming" session. An individual with diverging style has Concrete Experiment (CE) and Reflective Observation (RO) as dominant learning abilities. People with this learning style are best at viewing concrete situations from many different points of view. People with a diverging learning style have broad cultural interests and like to gather information. They are interested in people, tend to be imaginative and emotional, have broad cultural interests, and tend to specialize in the arts. In formal learning situations, people with the diverging style prefer to work in groups, to listen with an open mind, and to receive personalized feedback.

Assimilating Learning Style - An individual with an assimilating style has Abstract Conceptualization (AC) and Reflective Observation (RO) as their dominant learning abilities. People with this learning style are best at understanding a wide range of information and putting it into concise, logical form. Individuals with an assimilating style are less focused on people and more interested in ideas and abstract concepts. Generally, people with this style find it more important that a theory have logical soundness than practical value. The assimilating learning style is important for effectiveness in information and science careers. In formal learning situations, people with this style prefer readings, lectures, exploring analytical models, and having time to think things through.

Converging Learning Style - An individual with a converging style has Abstract Conceptualization (AC) and Active Experimentation (AE) as dominant learning abilities. People with this learning style are best at finding practical uses for ideas and theories. They have the ability to solve problems and make decisions based on finding solutions to questions or problems. Individuals with a converging learning style prefer to deal with technical tasks and problems rather than with social and interpersonal issues. These learning skills are important for effectiveness in specialist and technology careers. In formal learning situations, people with this style prefer to

experiment with new ideas, simulations, laboratory assignments, and practical application.

An Accommodating Learning Style - An individual with an accommodating style has Concrete Experiment (CE) and Active Experimentation (AE) as dominant learning abilities. People with this learning style have the ability to learn from primarily "hands-on" experience. They enjoy carrying out plans and involving themselves in new and challenging experiences. Their tendency may be to act on "gut" feelings rather than on logical analysis. In solving problems, individuals with an accommodating learning style rely more heavily on people for information than on their own technical analysis. This learning style is important for effectiveness in action-oriented careers such as marketing or sales. In formal learning situations, people with the accommodating learning style prefer to work with others to get assignments done, to set goals, to do field work, and to test out different approaches to completing a project.

Understanding the preferred learning styles is crucial in order to design effective instructional material that are targeted in the right direction. Moreover, studies are showing that retention and long-term memory is greatly enhanced and students' achievements increases if learning style preference is considered and applied to the mode of instruction (Pruet, Ang & Farzin, 2014). Due to the fact that this research is anchored to the NG student and enhancing their learning, the researcher confidently identifies that these students are generally *Accommodators* for they have proven and confirmed that they have a preference for experiential learning (Oblinger & Oblinger, 2010; Romita & Marin, 2014). This places their learning style between *Concrete Experience* and *Active Experimentation* as most of their learning is attained through doing and actively experimenting (Oblinger & Oblinger, 2005). The Coloured quadrant in Figure 1 below highlights this preferred learning style as the researcher has merged the Learning styles combined with the Experiential learning Model.

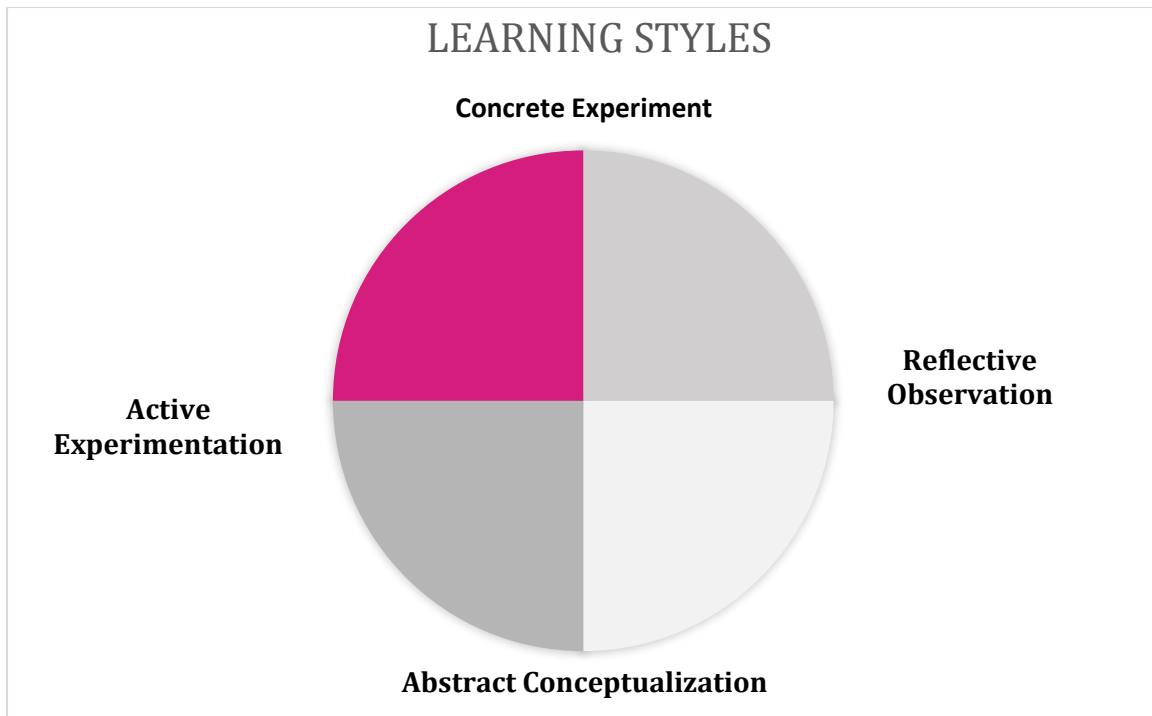


Figure 1: NG's Preferred Learning Style

Once a preferred learning style has been adapted by a NG student, the greater their learning orientation. Bertelson and De Gelder (2004) posit that a NG student, being humans, just like many other organisms possess multiple sensory systems and through these, sensing and learning the world this way is beneficial because different sensory modalities can detect and respond collectively to the same stimulus. In relation to that, the classroom of today, the learning environment is filled with capable distractions that may often arise from the technology they are engaged in. For instance, the student might hear the teacher's voice better if they can see the face and lip movements of that teacher (Bertelson and De Gelder, 2004). The capacity of the human brain to synthesise the multi-modal information arising from a common source enables students to direct their attention accordingly, if however the brain receives conflicting information from the differing modalities then our perception of events will become confused and down-graded, as illustrated by the 'McGurk effect' (McGurk & McDonald, 1976). This suggests that multi-modal perception is beneficial for a learner and that if one mode is less efficient for any reason or fails completely, perception will be facilitated by the other modes involved (Bertelson and De Gelder, 2004) and might constitute poor transfer of the knowledge.

Aligning 21st century learning with 21st century learners is the main problem teachers face nowadays (Romita & Marin, 2014). Learning in the 21st century seems to be focusing on the idea that students are more likely to be interested in what they are learning and motivation is geared towards understanding new concepts and skills that are more relevant and applicable to their lives other than in academia. Romita & Marin (2014) add by arguing that the NG students will be better prepared to succeed in various situations and have higher chances of excelling in their lives when presented with realistic problems or projects that are more familiar to them and their personal lifestyles. In the context of a knowledge based society, in which this study is conducted in, the main issue is to form and develop in the NG student the competencies of learning how to learn and by finding the most effective means towards it.

The review of the ELT enabled the researcher to determine what type of learners the NG are and how to tailor their learning material to best suit them. It has also shown various kinds of learning styles that are not to be discarded as not applicable to the NG, but rather as the less preferred. Confirming that the NG are dominantly *Accommodators* in their learning style, deductions can be made that a more engaging tactic is going to be more effective in the classrooms of today. The next section looks into the second theory-lens. Here, discussions will be shared on how learning can be more engaging by understanding the cognitive theory of multimedia learning and showing that multimedia learning is a superior method compared to the traditional 'chalk and board' style.

2.3 Cognitive Theory of Multimedia Learning

The cognitive theory of multimedia learning (CTML), created by Richard Mayer, is a theoretical framework that guides design principles for multimedia teaching (Clark & Mayer, 2011). It refers to multimodal processes within perception (intake of information via ears and eyes) and the sub systems in the working memory. The chief aim of the CTML is the focus on identifying difficulties that may arise during learning with texts and images and how to avoid them. Multimedia learning can be defined as learning from words and pictures whilst multimedia instruction is defined as presenting words and pictures that are intended to foster learning. The words can be printed (e.g., on-screen text) or spoken (e.g., narration). The pictures can be static (e.g., illustrations, graphs, charts, photos, or maps) or dynamic (e.g., animation, video, or interactive illustrations) (Mayer, 2009). CTML is based on three cognitive science principles of learning which are; dual channels, limited capacity and active processing. To further expound on these three pillars of CTML, Table 2 below describes each of the cognitive assumptions in detail (Mayer, 2009):

<i>Assumption</i>	<i>Description</i>
Dual channels	Humans possess separate channels for processing visual and auditory information
Limited capacity	Humans are limited in the amount of information that can be processed in each channel at one time
Active processing	Humans engage in active learning by attending to relevant incoming information, organizing selected information into coherent mental representations, and integrating mental representations with other knowledge

Table 2: Cognitive Assumptions

For some time now, illustrating text has been known to enhance memory (Paivio and Csapo 1973), pictures of objects are seemingly more easier to remember than their names, and illustrations do produce additional brain activity over and above that produced by experiencing each mode separately (Beauchamp et al., 2004)

A fundamental hypothesis seen in research on multimedia learning is that instructional multimedia materials that are developed with the knowledge of how the human brain works are more likely to achieve meaningful learning than those that are not (Rummer et al., 2011). Mayer (2003) reinforces by stating that meaningful learning occurs only when the learner engages in five distinctive cognitive processes which are: Selecting Words; Selecting Images; Organizing Words; organizing images and Integrating. Given that these process have been presented as a list, they do not essentially occur in this order, it is possible for a learner to move from process to process in many different ways (Mayer, 2003). Table 3 below further expounds on these processes:

<i>Process</i>	<i>Description</i>
Selecting words	Learner pays attention to relevant words in a multimedia message to create sounds in working memory
Selecting images	Learner pays attention to relevant pictures in a multimedia message to create images in working memory
Organizing words	Learner builds connections among selected words to create a coherent verbal model in working memory
Organizing images	Learner builds connections among selected images to create a coherent pictorial model in working memory
Integrating	Learner builds connections between verbal and pictorial models and with prior knowledge

Table 3: Cognitive Processes

The application of these processes do not happen as a whole, rather learners apply these processes segment by segment. The selection of images or any auditory message and finally integrating them applies at every section of a given material, and this set of processes is repeated for the next sections and so on.

Multimodal learning environments allow instructional elements to be presented in more than one sensory mode. Visual, Aural and Written (Moreno & Mayer, 2007). People have the ability to integrate information from different sensory modalities such as the eye, nose and ear which altogether create a meaningful experience (Ferri and Paolozzi, 2009). In turn, resources that are presented in an assortment of presentation modes may lead learners to perceive that it is easier to learn and this

will naturally improve their attention leading to an improved learning experience and performance. Mayer (2003) contends that students learn more efficiently and deeply from a combination of words and pictures than from words alone that may be the classic learning space of the teacher or instructor; this is also known as the 'Multimedia Effect'. More research following this particularly in the neuroscience sector reveals that “significant increases in learning can be accomplished through the informed use of visual and verbal multimodal learning” (Fadel, 2008, p. 12). Figure 2 below illustrates the Cognitive theory of Multimedia learning incorporating the aforementioned cognitive processes.

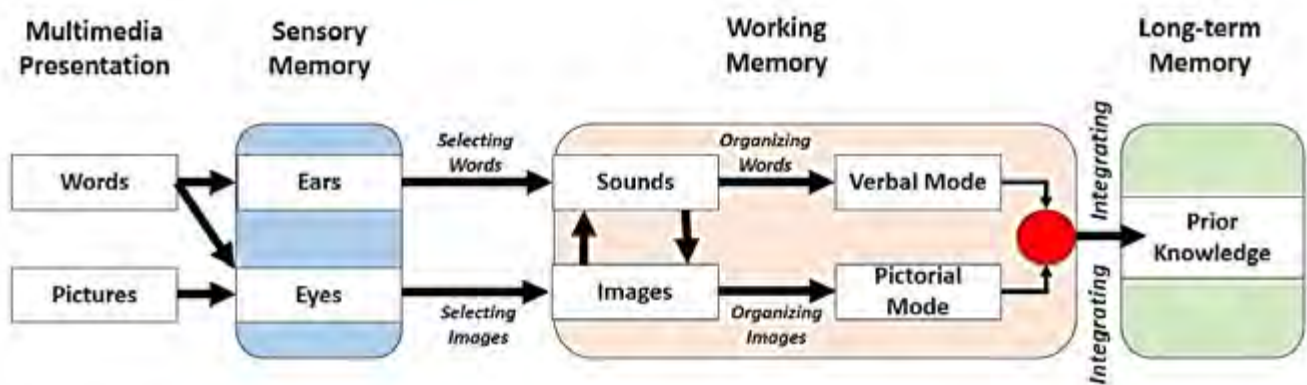


Figure 2: Cognitive Theory of Multimedia Learning

According to Issa et al. (2013 p.3) effective designs “help learners attend to relevant information, organize it into a coherent mental representation, and integrate it with prior knowledge.” However, poorly designed materials also have a negative impact; as too much information can overwhelm and confuse the learner. It is with this awareness that the educational instructor encounters a need or a demand really; viewing from the students’ point of view, to choose between several combinations of modes and modalities to promote more meaningful learning than there might have been otherwise. As seen earlier, Mayer (2011) has conducted extensive research in this area. His research has identified specific principles for designing learning material that can effectively elevate the learner experience for a meaningful and

memorable learning experience. A blend of previous studies and the research done by Mayer (2003) have discovered that these principles can improve learner attention (the ability to remember what was presented) and learner transfer (the ability to apply what has been learnt to overcome and solve problems). The principles that help align this research will now be discussed in detail as found by Mayer (2004):

Modality Principle 1: The first principle of modality states that when animation and narration are used together the student's learning is enhanced compared to when animation is used alone.

The Modality Principle 2: the following modality principle states that the combination of animation and narration is superior to a combination of animation and text. The rationale behind this principle is that the presentation of animation and on screen text together overloads the visual channel while the use of narration spreads the workload between both the auditory and visual channels.

Redundancy Principle: According to the cognitive process theory, learners can only process a certain amount of information. Too much information or information that is not clearly presented, or relevant, may lead to cognitive overload which has a negative impact on learning.

Personalization Principle: The personalization principle suggests that designers should promote a deeper engagement with learners and so they should aim to create learning material that students can relate to.

Multimedia learning takes place within the learner's information system - a system that contains separate channels for visual and verbal processing, a system with limitations on the capacity of each learner. These very multimedia are what the NG are constantly exposed to on a day to day basis and to find a way to encourage learning through these modes is exactly what this theory proposes.

CTML and its learning principles is the main view finder in which this study is based upon; the need to approach learning in a well-informed, superior manner. This is why it is the chosen guide by the researcher in advising creators of MTs in the considerations they ought to make whilst developing any new educational technologies. In the same light, it will also be used as a lens to reinforce and justify the results that will be obtained in this study.

By looking into learning, its definitions thereof and various schools of thought about how to best achieve it, the following section will now focus on the learner who is the NG student. Highpoints on their unique competences that differentiate them from the older generations of learners will also be discussed.

2.4 The Net Generation (NG)

Analysts on education are arguing that a new set of students are entering into educational institutions. One which has grown up with information and communication technology as an integral part of their daily lives (Howard-Jones, 2014).

Net Generation (NG) student, also known as the Millennials, Generation Y (McCrinkle, 2006) and the Digital Natives (Prensky, 2005) is the term used to describe the generation born between 1982 and 2003 (Berk, 2009b). The term 'Net Generation' was first mentioned by Tapscott (1997), they are said to have a natural aptitude and high skill levels when using new technologies (Jones, Ramanau, Cross, & Healing, 2010). The NG have grown up immersed in technology that continually becomes more powerful and compact, literally cyberspace in their pockets (Duffy, 2008). Looking at the term *Net Generation*, the prefix 'net' is an acronym for 'internet' owing to their fluency in the digital language of computers and the internet (Helsper, 2010). For this study, the researcher adopts the definition by Berk (2009) as being born between 1982 and 2003 and the term NG will be in reference to them.

2.4.1 Claims about the NG

Immersion in this technology-rich culture is said to influence the skills and interests of the NG in ways significant for education, and unlike their teachers, they show great interest in the use of technology in education (Friedrichsen et al., 2011). It is asserted, for example, that NG learn differently compared with past generations of students. They are held to be active experiential learners, proficient in multitasking, and dependent on communications technologies for accessing information and for interacting with others (Oblinger & Oblinger, 2005; Prensky, 2001a, b; Frand, 2000; Tapscott, 1999). Tapscott (1999), for example, described education in developed countries as already in crisis with more challenges to come 'There is growing appreciation that the old approach [of didactic teaching] is ill-suited to the intellectual, social, motivational, and emotional needs of the new generation' (p. 131). This was echoed by Prensky's (2005a) claim that: "Our students have changed radically. Today's students are no longer the people our educational system was designed to teach" (p. 1).

2.4.2 Criticisms of the NG

Inasmuch as the publicity of the NG has been renowned to be focused towards changing the teaching methods to suit their learning styles, the researcher is also objective to note the criticism that comes along with the generalisation of the NG student. As there is a variety of suggestions as to how to educate the NG, the generalisation of a generation and their characteristics can be limiting (Roodt & Peier, 2013). The notion that the learning styles of the NG differs from their predecessors has been challenged by several authors. Notably, in a study by Margaryan et al. (2011), it showed that there was no evidence yet to support the claims that the NG expect more technological integration in their learning content and in real essence, the NG still rely on instructional direction from their teacher and the methods that they then choose to use. It appears to be, according to Jones (2010) that the NG is not as homogenous as originally perceived. Different variables such as age, field of study, exposure to technology and teaching approach can influence the way the NG consume technology, both in educational and social contexts (Jones et al., 2010; Roodt, 2013).

Jones and Healing (2010b) noted that age was a large factor in determining the use of collaboration and communication technologies and there was no significant difference in skill levels of males and females. Beck (2009b) then reinforces by stating that defining and classifying groups of people and attributing characteristics to them often leads to misrepresentation and generalisation.

2.4.3 Skillset and Use of Technology amongst the NG

Technology, is said by Frand (2000), to have taken such a deep paving into their daily lifestyles that young people do not even consider computers 'technology' anymore.

In the previous sub-section, it was argued that Berk (2009b) noted that defining and labelling groups of people and ascribing characteristics to them can lead to problems of misrepresentation and generalisation. Based on research done by Jones et al, (2010); Kennedy, Judd, Dalgarno, & Waycott, (2010); Margaryan, Littlejohn, & Vojt, (2011), they have shown that the NG is not homogenous in their use of technology and thus some of the assumptions made about the NG are not entirely true. All the same, studies from different parts of the world that that would naturally prove to offer

different environments for children to grow up in, do show that the NG students tend to carry underpinning similarities in their consumption of technology. For example, a survey of 4374 students across 13 institutions in the United States (Kvavik, Caruso & Morgan, 2004) found that the majority of respondents owned personal computers (93.4%) and mobile phones (82%), but a much smaller proportion owned handheld computers (11.9%). The most common technology uses were word processing (99.5%), emailing (99.5%) and surfing the Net for pleasure (99.5%). Later on, these findings were further supported by another study carried out in Australia showing similar patterns in the use of MTs (Oliver & Goerke, 2007). In summary, the evidence indicates that a proportion of young people are highly adept with technology and rely on it for a range of information sources and a major means of communicating with peers and family members.

2.4.4 Learning Style Preferences of the NG

It is widely debated that the NG are accustomed to learning at a much higher speed, handling visual and dynamic information, learning through game based activities and making random connections (Prensky, 2005; Bavelier et al., 2012). Bankole & Brown (2011) additionally posit that it is because of these factors, young people seem to prefer discover-based learning that gives them room to actively test their own ideas and later on, create knowledge. In light of these learning preferences, Oblinger & Oblinger (2005) noted several characteristics of the NG that have shown to have an impact on higher education institutions. These characteristics are (Oblinger & Oblinger, 2005, p. 10):

- Digitally Literate – the NG interacts with technology on a regular basis and feels comfortable using technology
- Connected – they have access to and are connected to a technological network such as a cell phone network or social network
- Immediate – they expect immediate responses from technology and often multitask
- Experiential – they prefer to learn by doing and prefer practical learning environments

- Social – they are comfortable sharing personal information and interact with one another across various platforms
- Teams – they prefer to learn and work in teams
- Structure – they prefer structure as opposed to ambiguity in their learning
- Engagement and Experience – they prefer interactivity and interactive teaching materials
- Visual and Kinaesthetic – they prefer visual teaching materials such as images as opposed to static teaching materials such as notes
- Things that Matter – they prefer to learn about issues that matter, such as environmental and economic concern

However, all these changes that may seem as benefits to the NG have come with challenges of their own. A key challenge is that educating the NG is strong becoming a concern because engaging these very students is proving to be a difficult task (Merlino & Rhodes, 2012; Berk, 2009b). Literature indicates that there have been critical dialogues between institutions to try and figure out what the best approach is to best engage the students. These suggestions include adapting teaching methods (Wilson & Gerber, 2008) and using real world examples to create teaching strategies by creating participatory activities (group work and projects) for the NG. These activities are believed to stir in them greater motivation due to their learning preference of exploration and experimentation (Merlino and Rhodes, 2012). Student engagement and its key factors are consequently discussed and thereafter an argument on application of technology in learning and what effects it has on the student as a whole.

2.4.5 Student Engagement

Understanding the level of which the NG student is engaged is vital to determine the effect that MT in the classroom offers towards their learning. Axelson and Flick (2011) refer to student engagement as "how involved or interested students appear to be in learning and how connected they are to their classes, their institutions and each other" (p.38). Roodt (2013) confirms that student engagement has had a long history and it can be traced back to as early as 70 years ago with research carried out in the 1960's and 1980's focused on the quality of effort put forward by the student to measure the level of engagement. Seemingly, the desire to engage the student in learning has been consistent with efforts of instructors to teach more effectively. Studies have been able to pinpoint three different categories of student engagement; these categories are behavioural, emotional and cognitive engagement (Pike, 2006; Axelson & Flick, 2011; Roodt, 2013).

Behavioural category explains that, recognition was given to positive conduct, involvement, effort and participation. In addition, Axelson and Flick (2011) added that behavioural engagement was action from the student that could be observed. Emotional engagement reflects to the students' affective reactions such as enjoyment, interest, or a sense of belonging (Pike, 2006). Cognitive engagement stresses investment in learning and involves self-regulation and being strategic (Fredericks et al, 2004; Roodt, 2013). According to Finn and Zimmer (2012) cognitive engagement can also be referred to as students going the extra mile beyond the minimal requirements, and thus used to facilitate learning of complex material. Finn and Zimmer (2012) stated that going beyond the minimal requirements includes getting clarification for concepts by asking questions, persisting with difficult tasks and reading extra material over and above the prescribed material.

Researchers expected to find that the NG students highly prefer to be taught in classrooms that are greatly geared with technology in order to be better engaged. Surprisingly, what Oblinger & Oblinger (2005) found is a bell curve with a preference for a moderate use of technology in these very classrooms as shown in Figure 3 below; supporting earlier discussions on the NG and their reliance on instructional guidance from their teachers. A strong preference to '*Classes with moderate IT*' with the

instructor incorporating MT into the learning material and maintaining that balance throughout the session.

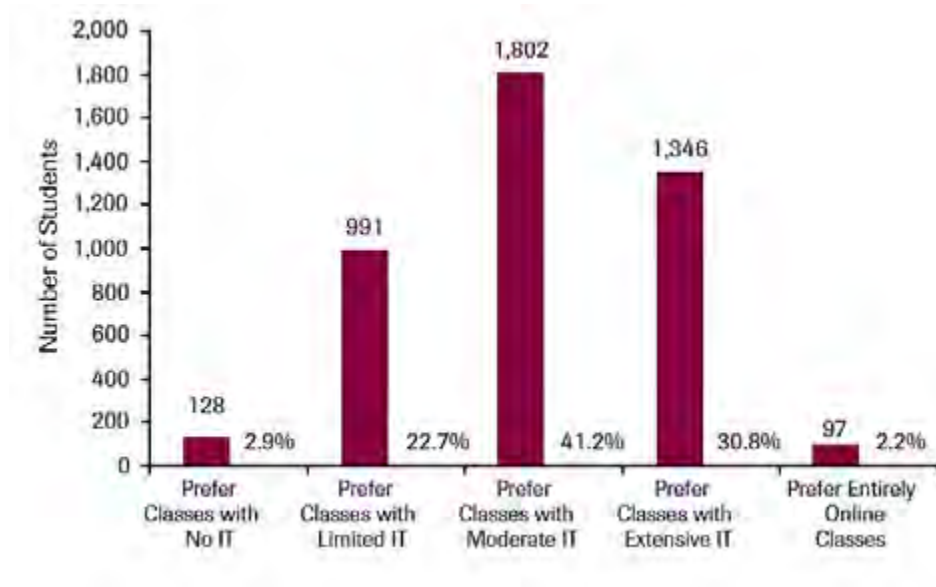


Figure 3: Technology preference of NG students in Classrooms

In numerous ways, technology has richly equipped education methodologies adding a new dimension to the old ways and archetypal teaching methodologies. So far, this literature review has looked at learning and what researchers broadly believe it to be; the need for the teaching instructions to be modified in order to cater to the NG student and the preference that these students have in their learning styles inasmuch as they have grown up immersed in a technology-oriented world.

The following section will explore an assortment of technologies aiding in education and learning in their various ways, whether they truly enhance learning and what is best suited for the NG's cognitive development.

2.5 Technology in Learning

Early in the 20th century, Thomas Edison quoted as a forecast, "It is possible to teach every branch of human knowledge with the motion picture. Our School system will be completely changed in ten years" (Reiser, 2001, p. 98). Seeing that this did not materialize exactly as predicted, in a not so different way, computers and technologies over the decades have been applauded for their potentially transformative chattels. It is evident that they have growing impacts in most aspects of human endeavour and it was a matter of time before it is to be suggested as a use, means or medium of learning in our educational institutions (Bavelier, Green, & Dye, 2010).

Keeping in mind that the NG student is the learner of today, it is not a far-fetched idea by instructors and leaders thereof to find a means to leverage technology towards obtaining teaching and learning goals. Thus, in this context, schools are faced with a dual challenge between understanding how well-designed technology improvements can enhance a student's educational experience and being willing to examine concurrent changes in pedagogical methods (Rose, David and Cook, & John, 2006). Firstly, the researcher examines whether access to these various MTs pose a challenge before recommending their dominant use in learning. The following is a brief look into current studies that represents the NG and their access to technology.

2.5.1 Access to Technology

There have been longitudinal studies on the extent to which the NG have access to these MTs that are claimed to have 'moulded' their growth, which in turn may make it an obvious precursor to their use.

In surveys of university students, for example, have shown that access to some technologies is almost universal. This is because very high proportions of students have access to their very own mobile phone and sole access to either a laptop or a desktop computer (Margaryan & Littlejohn, 2009; Bennett & Maton, 2010). The same studies show that access to other technologies is more varied, or in the case of handheld computers, quite limited. The key reasons for the lesser popularity of these devices, as explained by students in the study's focus group interviews, have been their high cost and lack of distinct advantage over technologies that students already

use (Caruso & Salaway, 2007). This is understandable given that young people are sensitive to cost and often opt for less expensive alternatives.

Some longitudinal surveys, like the ongoing ECAR (Study of Undergraduate Students and Information Technology) (2014) partnered with 213 higher education institutions across 15 countries, show that some technologies become more popular, while others decline. Recent examples are the increase in laptop computer ownership and broadband access among students, with a decline in dial-up Internet use. Now more than ever, more students have experienced a digital learning environment and a majority say they learn best with a blend of online and face to face work, supporting the earlier mentioned findings of Oblinger & Oblinger (2005). It was also shown that many students now own mobile devices than before and they also use them for academic purposes. Instructors do encourage in-class use, but faculty is concerned about their potential for distraction (ECAR, 2012).

While this longitudinal study goes to provide useful insight towards the array of technological devices available to the NG, the task now remains to encourage the study of computers and other multimedia use for their potential to foster better achievement in schooling and learning.

2.6 Technology Enhanced Learning (TEL)

Technology and the use of multimedia, like any tool, its effectiveness is determined by the purpose it serves and the manner in which it is implemented (Schmidt et al., 2014). At the very core, Technology Enhanced Learning (TEL) seeks to enhance the student learning experience whilst sustaining student engagement and enhancing retention. Figure 4 below highlights the main aims of TEL following studies by Trepule et al. (2015). Researchers are in tandem when they say that technology cannot improve educational processes, in its stead, it should be for using it innovatively to make learning more efficient and more attractive to learners (Trepule et al., 2015).

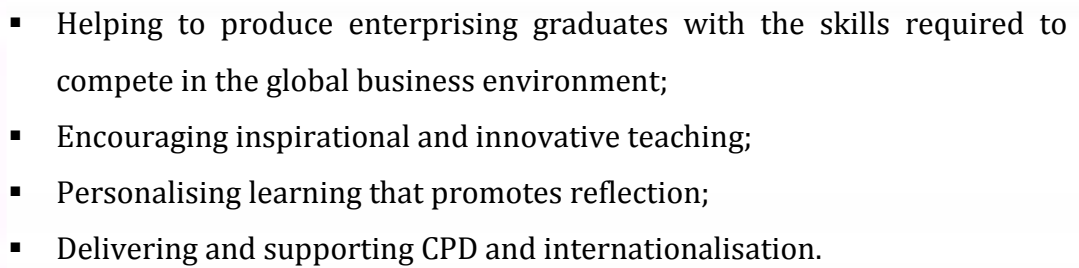
- 
- Helping to produce enterprising graduates with the skills required to compete in the global business environment;
 - Encouraging inspirational and innovative teaching;
 - Personalising learning that promotes reflection;
 - Delivering and supporting CPD and internationalisation.

Figure 4: Aims of TEL

Learning and technology are no longer considered as didactic rivals, TEL should therefore be designed to maximize the learning for the learners and learning should be the driver of the technology and not vice-versa. This way, the student is not subservient to the technology and functions are carried out as originally intended allowing the NG student to focus on the actual learning for its intended future use. One of the major advantages of TEL is its capability to present students with more information than it has ever been possible before (Srisawasdi & Panjaburee, 2014) with its possible simulations on real life tasks and concentration on performance. Equipping classes with the best, most updated technological instrument does not equally mean “it will improve the learning process of students, allowing people to be more efficient, because, in spite of these outward changes, the student experience remains similar to that of generations ago” (Rose, David and Cook, John, 2006:21).

2.6.1 Factors Encouraging TEL

In support of the use of TEL, a report that was carried out by Walker (2014) focused on identifying which factors are the main contributors towards promoting and the development of TEL within the learning institutions. Table 4 below gives a summary of the findings:

RANK, 2014	Driving Factors	Average Mean/5
1	Enhancing the quality of learning and teaching in general	3.83
2	Meeting student expectations	3.73
3	Improving access to learning for students off campus	3.27
4	Improving administrative processes	3.15
5	To help create a common user experience	3.12

Table 4: Driving factors of TEL

It is noted that the top three drivers for the development of TEL have remained unchanged for the past two years with ‘enhancing the quality of learning and teaching’ being the leading motivation (UCISA, 2014). In another report by Bayne (2014), two fundamental needs were brought to light that were declared essential in enhancing the learning experience of the NG students. These are: The NG should not be ignored and their education must fundamentally be improved to meet the needs of these new student entering into the institutions. These two points tie very well with the first two driving factors as identified in the table above; primarily to adjust, if not to change, the old methods of didactic teaching that is ill-suited for the NG (Prensky, 2005).

The debate around the effectiveness of technology for improving student learning has been carried on for over three decades. According to literature, the most widely cited debate was between Clark (1983) and Kozma (1994). Clark (1983) first argued that technology had no impact on student learning under any condition and said "multi media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition." He strongly stood by the fact that technology and its impacts on student learning was mainly due to unique effects or instructional strategies, but not technology itself. Kozma (1994) reacted to Clark’s argument by saying the analogy of

“delivery truck” creates an “unnecessary schism between medium and method”. Kozma believed that technology had an actual impact on student learning and played an important role in student learning.

The Clark–Kozma debate of three decades ago has been since outdone by the extraordinary advances in technology and its applications in learning in recent years. It may be theoretically interesting to ask whether the impact of technology itself can be separated from the impact of particular applications, but as a practical matter, machine and method are intertwined (Cheung & Slavin, 2012).

Studies continues to show that technology is proving to be a double edged sword. At a U.S. study conducted at UCLA (Small et al., 2013), it has revealed some alarming information about the developing brains of young people and their involvement with technology. They’re spending upwards of 7 hours a day attached to their iPads, smartphones, gaming consoles and computers. And the effects to their brains are proving to be very damaging. “Digital Dementia”, a term coined by top German neuroscientist Manfred Spitzer in his 2012 book of the same name, is a term used to describe how overuse of digital technology is resulting in the breakdown of cognitive abilities in a way that is more commonly seen in people who have suffered a head injury or psychiatric illness. Also, in the UK telegraph (Ward, 2013), a report shows that a girl aged four is having psychiatric treatment after becoming Britain's youngest known iPad addict. With the increased inactive time children are spending with technology and reduced time in playing outside, links are being drawn between overuse of technology and a delay of the NG's achievement of sensory (such as taste, touch, vision, hearing, and smell which develop through movement and exploration) and motor milestones (the ability to use large muscles for movements such as crawling, or walking) (Rowan, 2010) and reduced academic performance (Wood et al., 2012). The overuse of technology has also been associated with sleep difficulties and increased anxiety, depression and isolation in some cases, particularly when children are exposed to personal safety risks such as cyberbullying (Farber & Shafron, 2012). Not only so, but in the earlier case stated of the child who is undergoing psychiatric treatment, She is one of many child patients displaying compulsive behaviour after using the tablet device from an early age. Seemingly, technologies that

were initially developed for the purpose of enhancing cognitive abilities, may lead to no effects or, worse, may lead to unanticipated negative effects (Owen et al., 2010; Moser et al., 2015).

If technology has any chance to be effective, for technology to become an integral aspect of classrooms and curricula, its use must be a regular, integral part of an instructional program and not viewed as an add-on. The changes in teacher and student behaviours must, of necessity, be fundamental to the system (Deubel, 2003). While there are certainly innate or genetic limitations to our various capabilities, a large part of who we are is shaped by our experiences (Kolb, 2005) - and these same experiences today are shaped by the influence of technology that surrounds the growing NG, both at home and in schools. This fact is inevitably relevant to the NG student and the reason is primarily because they are at the forefront of the technological revolution (Rideout, 2006). In the next two sub sections, the researcher briefly highlights the acceptance of new technologies into our learning institutions and potential barriers that have been faced in the last decade.

2.7 Technology Acceptance

Researchers have identified the conditions or factors that facilitate technology integration into learning institutions. And over time, models were developed and tested to predict technology acceptance. There are numerous theories that have been established, theories such as Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Expectation-Confirmation Theory (ECT). Amongst an array of these models, the Technology Acceptance Model (TAM) is arguably the most popular (Davis et al., 1989; McCoy et al., 2007; Toft et al., 2014). With empirical support and its frugal method in predicting technology acceptance, it has been extensively tested and validated among users over the years (Teo, 2009) and is the most cited of theories in a majority of literature for it has been applied in over 580 articles on acceptance of technology (Cheung & Slavin, 2012; Toft et al., 2014). According to the TAM model, the acceptance of a new technology greatly relies on the facts that the technology is easy to use and useful for achieving a goal.

However, new technology can have a reciprocal relationship with educators. The introduction of new technologies pushes educators to take advantage of them and requires the teachers to understand the technology well enough to be able to leverage them in the most effective ways (Klopfer et al., 2009). In this pursuit, the new technologies encounter some barriers which slow down their implementation. This is shared briefly below.

2.7.1 Barriers to Implementation of Technology

Listed below are the potential barriers that have been noted over the past decade against TEL. Figure 5 below gives an overview of these barriers and they are later expounded in more detail.

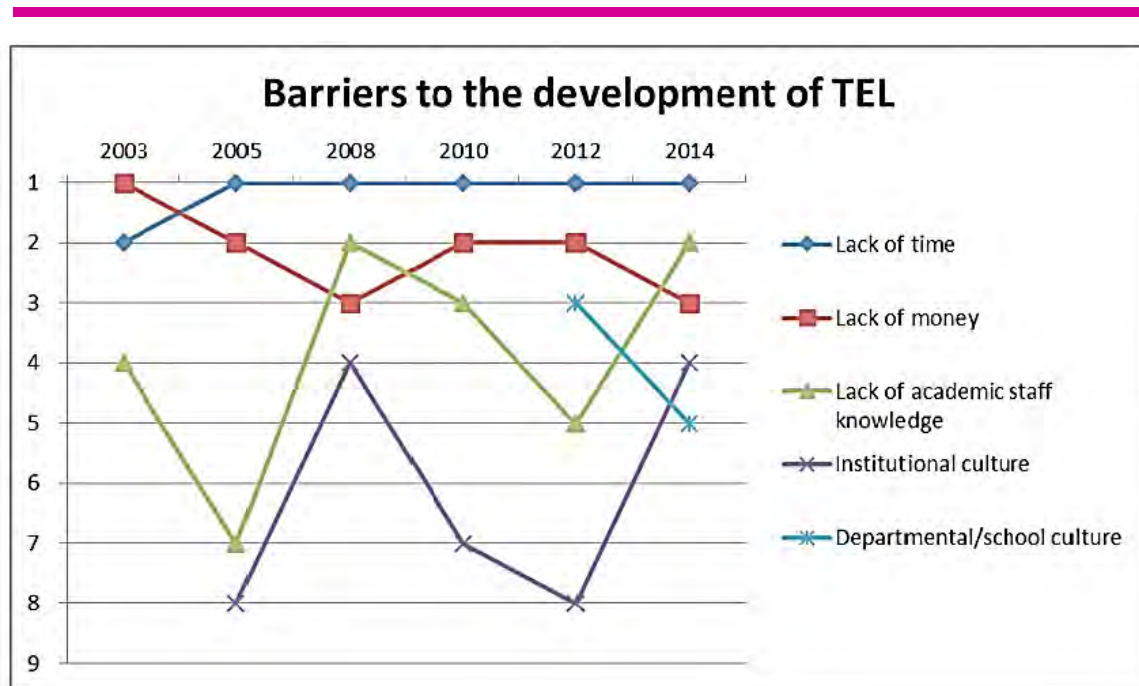


Figure 5: Barriers to the development of TEL

The top three barriers as indicated in the figure above are the institutional culture i.e. the culture of the teachers and students in the institution; the lack of academic staff knowledge and thirdly, the lack of money to implement certain measures that look into the support of TEL within an institution. It is evident that inasmuch as researchers might greatly advocate for TEL in institutions, faculties of these schools have clearly outlined the major issues towards these modern technologies. To be able

to effectively use these new technologies in learning institutions, these barriers need to be addressed (Toft et al., 2014).

If technology has any chance to be effective, for it to become an integral aspect of classrooms and curricula, its use must be a consistent, essential part of an instructional program and not viewed as an add-on. The changes in teacher and student behaviours must, of necessity, be fundamental to the system (Deubel, 2003). While there are certainly innate or genetic limitations to our various capabilities, a large part of who we are is shaped by our experiences (Kolb, 2005) - and these very same experiences are today shaped by the influence of technology that surrounds the growing NG, both at home and in schools. It is for this reason that the main objective of this study is to develop a model that will guide consumption of technology for the NG student, to progressively curb lifelong negative effects of technology on cognitive development.

On the other hand, studies of Green and Bavelier (2014), show that engaging in other modes of MT such as playing of video games is associated with a number of enhancements in vision, attention, cognition and motor control. Devoted players did show top-down control of attention and are able to choose among different options more rapidly (Hubert-Wallander et al., 2010 and Dye et al., 2009a). They also exhibit better visual short-term memory (Boot et al., 2008; Green and Bavelier, 2006), and can more flexibly switch from one task to another (Boot et al., 2008, Colzato et al., 2010 and Karle et al., 2010). These enhancements have been found to have real-world applications and is more so seen in how they can play an integral part in an environment that requires learning. In other institutions adopting game based learning, they are finding increased engagement and motivation amongst students; greater connections in transfer of learning and in curriculum being demonstrated by the students; dramatic increase in the quantity and quality of student writing and improvement in collaboration strategies with other students (Bavelier, 2014). According to the experiences of these schools, video games are able to have such an impact only because the manner in which these games are adapted are critically considered; whereby the game serves as the hook to connect the learning objectives and the activities defined by the curriculum (Groff, Howells and Cranmer, 2012).

Although each of the published studies provide burgeoning insights, the world does not yet know a fully grown NG of whom further conclusions can be drawn from. Only then would research be capable of answering the overarching question of the overall impact of technology use on student achievement. The debate cycle on the effectiveness of TEL bubbles up a plethora of questions and it will only remain a cycle and as long as new MTs are being developed. Technology is here to stay, and reasonably, the quest should be how to make the best use of the many technologies now available.

Having looked at the potential effects that various multimedia have both positive and negative, it all links back to the brain. The technology needs to be "brain friendly" so it fits and complements the cognitive processes of the students. If otherwise, its use may be detrimental. In cognitive neuroscience, 'learning' is often synonymous with memory. A memory of the content is created of which the student can willingly access in order to remember that particular piece of knowledge (Howard-Jones et al., 2014). There are regions proven to be primarily linked to memory and the fact that it has to be coded somewhere in the brain appears indisputable.

This study proposes to borrow from cognitive neuroscience and its experiments on the NG at different ages whilst engaging with different kinds of MTs. This study intends to use results from neuroscience experiments to further support claims that use of MT does have a physical effect on the brain and when used appropriately, it can have positive effects on the student and higher retention of the content they are trying to learn. The next section looks into cognitive neuroscience; its achievements thus far; the neuro-underpinnings of learning and its potential capabilities to guide effective consumption of multimedia and technology.

2.8 Bridging TEL and Cognitive Neuroscience

2.8.1 The Basics of Cognitive Neuroscience

The term 'cognitive neuroscience' was coined by George Miller and Michael Gazzaniga towards the end of the 1970s. Cognitive neuroscience is an academic field concerned with the scientific study of neural mechanisms underlying cognition (Gazzaniga, Ivry & Mangun, 2002). Neisser (1976) alternatively states that cognition is the process by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used; mental processing that includes the attention of working memory, comprehending and producing language, calculating, reasoning, problem solving, and decision making (Neisser, 1976). Cognitive neuroscience then endeavours to define how human behaviour and cognition can be classified into concepts that can be studied. This is towards understanding what part of the brain is responsible for which action and at what time in their lives (Jonides & Nee, 2006).

2.8.2 The Brain Structure

The human brain approximately contains one trillion nerve cells and each of them may communicate with between ten and ten-thousand other nerve cells. With a 'wet-weight' of only about three pounds, the human central nervous system is undoubtedly the most complex structure known to exist in the universe. In spite of its complexity, there is now a detailed understanding of the brain's building block – the neuron. But it's taken 2, 500 years to get here, and it has not been a smooth journey with such great discoveries of its general principles of inter-neuronal architecture and communication (O'shea, 2013). Brain cells (or neurons) transmit information via electrical signals, which pass from cell to cell via the synapses, triggering the release of neurotransmitters (chemical messengers). Understanding the ways in which neurotransmitters work is a major goal of neuroscience. Goswami (2006) explains further that patterns of neural activity are thought to correspond to particular mental states or mental representations. Learning broadly comprises changes in connectivity, either via changes in potentiation at the synapse or via the strengthening or pruning of connections (Hall, 2005). Successful teaching thus directly affects brain function, by physically changing connectivity (Howard-Jones et al., 2014). Armed with

such heuristics, neuroscience has made great strides in understanding what appeared to be a hopelessly complex gelatinous mass (Mangina, 2009).

2.8.3 The Engaged Brain in Learning

The notion that education has much to benefit from brain research has become increasingly popular. Also very noticeably, is the fact that cognitive neuroscience is making rapid strides in areas relevant to education and there is a growing hunger in schools for information about the brain (Leong & Goswami, 2014). The time for evidence-based learning is now and it is beckoning with determined goals for pedagogical experiments that may equally lead to breakthrough discoveries. Despite the observable fact that education is constrained by the architecture and functioning of the human brain, neuroscience has remained distant from classrooms (Sigman et al., 2014). The impact of these insights may be greatest where another force for change, technology, is already impacting the methods and means by which learning takes place. Several scholars like Ertmer et al. (2012) have argued that this disconnection has practical roots and are dubbing it as a 'bridge too far', with insisting that neuroscience and education need not agree. The researcher however argues that neuroscience, technology and education should work in synergy, providing complementary tools and for all to act in concert to improve education. The technology should take a guiding role to help the brain understand things, resulting in a reduction of cognitive load. The ideal learning situation is to have, as amply as possible, cognitive attention and engagement to focus on the learning materials. This will make learning quicker and the learners will remember the material better, greatly increasing the chances of using it (Cherrett, Wills, Price, Maynard, & Dror, 2009).

Neurobiology offers assistance and an understanding to the mechanisms by which learning occurs and meaning is constructed. The underlying theory of experiential learning helps to understand that the human brain can only develop through input from the environment and is referred to as experience-dependent plasticity, a process that continues well beyond adolescence (Johnson & De Haan, 2015).

The researcher continues to highlight how the studies of the brain holds the key to effective learning and how, when gelled with the right MT, can be more effective. The subsequent section looks into brain imaging technologies and different techniques that are currently used in laboratories worldwide for brain mapping.

2.8.4 Methods and Techniques in Brain Data Collection

In a modest selection of brain data collection techniques are carried out, them, which are currently being practised in the world of neuroscience and how they demonstrate their potential in providing new insights into the NG interactions with technology. At first, a slight history into the origin of neuro-imaging.

In 1906, Camillo Golgi and Santiago Ramon Cajal shared the Nobel Prize in medicine. The two men's work formed the basis for all that is known about the basic structure of the brain. In the 1870s, Golgi developed a means for staining the brain that was far more advanced than any other technique of its day. His staining technique allowed scientists to see for the first time the individual tissues and cells of the brain.

Since then, many technologies have developed and have led to the scientists of today being able to take real-time images of the normal functioning human brain. Figure 6 shows an example of an imaging technique that is currently used and a result of how a normal engaged or active brain looks like. The colour of each dot indicates the intensity of the energy that is recorded. Red indicates the highest intensity-in other words, the area of greatest brain activity and it decreases as you move down the spectrum as shown by this particular legend.

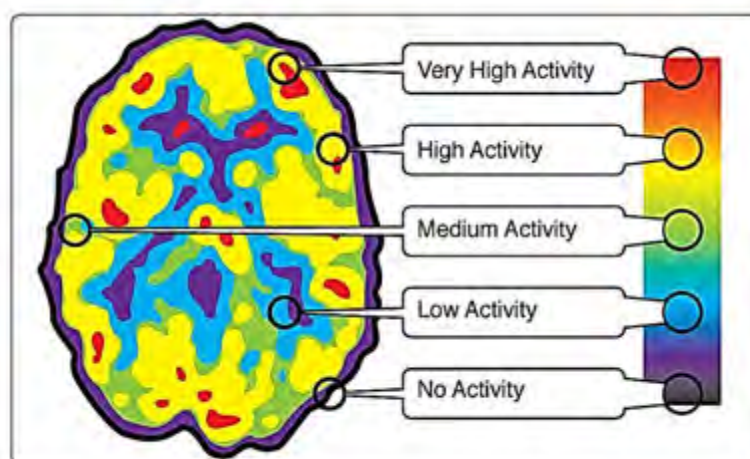


Figure 6: Brain Staining Techniques

This section discusses several brain imaging technologies that are now widely available and presents illustrations of how they are used. Commonly of which include the functional imaging techniques fMRI (functional Magnetic resonance imaging) and EEG (Electroencephalography) (Krägeloh-Mann & Marko Wilke, 2009). The imaging techniques are discussed below (Howard-Jones et al., 2014):

Functional magnetic resonance imaging, (fMRI), is a technique for measuring brain activity in which the participant is placed in a scanner. Due to its very strong magnetic field, it works by detecting the changes in blood oxygenation and flow that occur in response to neural activity – when a brain area is more active it consumes more oxygen and to meet this increased demand blood flow increases to the active area. fMRI can be used to produce activation maps showing which parts of the brain are involved in a particular mental process.

Computed tomography (CT) is an x ray procedure where the subject lies on a table that slides in and out of a hollow, cylindrical apparatus. An x-ray source rides on a ring around the inside of the tube with its beam aimed at the subjects head and with the aid of a computer, it generates cross-sectional views and, if needed, three-dimensional images of the

Magnetoencephalography (MEG) is an imaging technique used to measure the magnetic fields produced by electrical activity in the brain via extremely sensitive devices known as SQUIDS. The spatial distributions of the magnetic fields are analysed to localize the sources of the activity within the brain. These help in determining the function of various parts of the brain, neuro-feedback, and others.

Electroencephalography (EEG) is the measurement of the electrical activity of the brain by recording from electrodes placed on the scalp. The resulting traces are known as an electroencephalogram (EEG) and represent an electrical signal from a large number of neurons which generates at least four distinct rhythms (delta, theta, alpha, beta in order of diminishing wavelength)

Figure 7: Brain Mapping Tools

The emergence of innovative apparatuses stimulates the imagination of many researchers and scientists. The architecture and function of the brain is carved by a lifetime of experiences which affect the structure and purpose of neurobiological pathways (Mustard, 2010). At the same time, these pathways offer a blueprint of how to how influence them and induce learning at a more effective level.

The next section presents the theoretical framework employed in this study and why it is considered best fit for this research.

2.9 Piaget's Theory of Cognitive Development

The researcher intends to use Piaget's Theory of Cognitive Development (PTCD) as a compass in which studies to analyse; with support from neuroscience experiments, a dominant mode of perceiving information at a particular age can be confirmed.

Jean Piaget (1896-1980) was one of the most influential researchers in the area of developmental psychology during the 20th century. Trained in biology and philosophy, Piaget drew on concepts from both these disciplines to study the development of young children. Piaget's theory of cognitive development distinguishes four primary cognitive structures that correspond to four stages of development (Huitt & Hummel, 2003). His theory is one of the most enduring contributions of the 20th century (Ribaupierre, 2015).

In a quest for an individual to adapt, Piaget describes two processes: *Assimilation* is the process of using or transforming the environment so that it can be placed in pre-existing cognitive structures. *Accommodation* is the process of changing cognitive structures in order to accept something from the environment. Both processes are used simultaneously and alternately throughout life. As one's neural structures become more complex, they are organized in a hierarchical manner summarised as the four stages identified by Piaget as the 'Stages of Cognitive Development' (Upadhyay, 2011). Figure 8 below outlines these stages of development:

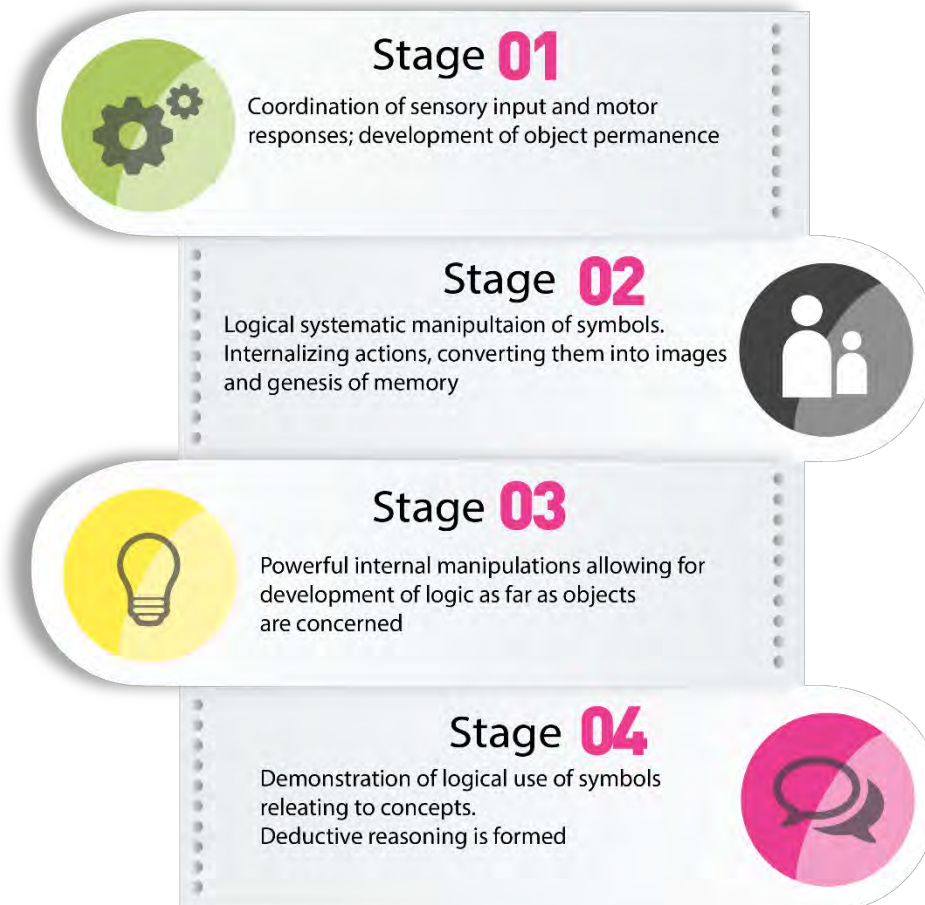


Figure 8: Stages of Cognitive Development

The Sensory Motor Stage (Stage 1)

In this stage, from birth to two years of age, the child is pre dominantly concrete and active in his learning style. Learning here predominantly works through feeling, touching and handling.

This is because the subject is trying to understand their environment. The idea is based on representation and the greatest accomplishment of this level is the development of a goal oriented behaviour.

The Pre- Operational stage (Stage 2)

This stage occurs between the ages of two years to six years. Piaget believes that the main aim of this stage is demonstrated through logical and systematic manipulation of symbols. Here the subject begins to internalize actions, converting them into

images and the genesis of memory and imagination begins. Small language development was also noted to have begun as a precursor to the next stages

The Concrete operational Stage (Stage 3)

The third stage, the concrete operational stage, begins from seven years old and continues until approximately eleven years old. For Piaget (1976), the term 'operational' is used to refer to logic of classes and relations; powerful internal manipulations such as addition, multiplication, division and ordering. The mastery of these processes allow for the development of logic as far as actual objects are concerned. In this stage the subject increases their independence from his immediate experiential world through the development of inductive capabilities. In comparison to the first stage which learning occurred in the accommodative style, here it switches to assimilative; relying on concepts to choose from to give shape and meaning to their experiences.

The Formal operational Stage (Stage 4)

The final stage, according to Piaget (1976), begins at approximately twelve years old and continues through adolescence and later into adulthood. Pre dominantly, intelligence is demonstrated through the logical use of symbols relating to concepts. Here the subject is able to engage in deductive reasoning. There is development of possible implications of theories and goes to experiment which are valid and which are not. However, instead of a trial and error type of approach, it is replaced with a more systematic problem solving technique. In this particular stage, the learning style predominant is convergent.

Piaget believed that biological development dictates the movement from one cognitive stage to the next (Upadhyay, 2011). This brief outline of Piaget's cognitive development theory identifies the basic developmental processes that ultimately shape the basic learning process of adults (Ribaupierre, 2015). Engaging the brain with several multimedia might stimulate brain growth/expansion and when tallied against neuroscience experiments, definitive conclusions to which technology is most appropriate at a particular cognitive developmental stage can be made.

2.10 Summary of the Literature review

The literature review discussed the three main themes in this dissertation. These are TEL, the NG and Neuro-education. The literature gave insight into the NG student and has highlighted the major difference in which learning occurs to them compared to the older generations. To add on to that, it has brought into light the rapidly growing use of MT in learning. TEL has been proven to have both positive and negative effects on the NG and the literature has shown the relationship between the use and the learning outcomes of the students. The core advantage is that TEL helps the cognitive system to learn. Not only did it enable quicker learning but the students' memory was improved, resulting in more use of that knowledge. In contrast, attention was brought to an over consumption of TEL and the direct effects it has on the brain. The potential negative effects on the development of executive functions were also pointed out. These outcomes have been based on evidence from neuroscience research. The researcher then proposed possible advantages of practical use of Neuro-education in the classrooms; primarily to engage the students by being certain that their cognitive resources and attention are properly used and focused.

The next chapter presents the research design that was used in this study.

RESEARCH DESIGN

3.0 RESEARCH DESIGN

Introduction

Following the literature review from the previous chapter, this chapter explains, in detail, the research methodology which the researcher has selected for this study. Thereafter, the researcher justifies the procedures mentioned and the selections made in line with this research. Baskerville & Myers (2009) state that a complete research should consist of the following five steps: A set of philosophical assumptions about the world; a research method; one or more data collection techniques; a written record of the findings.

3.1 Research Paradigm and Epistemology

At this stage, developing a philosophical perspective requires that the researcher make several core assumptions concerning two dimensions: either a subjective or an objective approach to research. These two major philosophical approaches are delineated by several core assumptions concerning ontology (reality), epistemology (knowledge), human nature (pre-determined or not) and methodology (Burrell and Morgan, 1979).

For this study, the ontological stance of the researcher is an objective one. Saunders et al. (2009) reviewed that Objectivism uses highly successful methods of the natural sciences to investigate social science phenomena and assumes that social entities do exist and external social actors i.e. humans, can be measured.

Based on the published Oxford English Dictionary (2014), it describes epistemology as “an established fact, theory, discipline or science of the technique process or foundation of knowledge, facts or information”. Holding the belief that the core of every research or study should be to come up with knowledge and fact, then subsequently, it has to depend on an understood (implicit) or open (explicit) epistemology (Aliyu et al., 2014). Koskinen (2013) widely described it as views surrounding nature, sources processes and interpretations of knowledge.

There are three main and dominant epistemological perspectives in social science research which are positivist, interpretive and critical perspectives (Myers, 2009).

Each of these perspectives will be discussed below and the researcher will highlight the reasons for selecting positivist paradigm for this thesis.

According to Kaboub (2008), the idea of positivism came into being as a truth-seeking approach in the later years of the 19th century through Auguste Comte's denunciation of metaphysics and his strong claims that only technical and scientific facts can disclose the reality concerning truth. Comte also viewed positivism as a method by which anything could be analysed (Aliyu et al., 2014). Positivist research approach and methodology that genuine, real and factual happenings could be studied and observed scientifically and empirically. The decisive factor for assessing and appraising the soundness and validity of a scientific and logical theory is whether a researcher's facts view point whether they are theory-based or pinned on guesses and hunches are reliable consistent and dependable by means of the knowledge (Aliyu et al., 2014). Lee (1991) sums it up by clarifying that positivism assumes complete independence on the researcher's side, the researcher is completely detached, neutral and objective in carrying out the study and their opinions and/or perceptions cannot influence the study.

This is the approach to epistemology that will be used by the researcher as this study primarily seeks to measure elements of human behaviour in a scientific manner (Grixx, 2002). The nature of this study is to measure the effectiveness of MT to the NG's brain inasmuch as there are socio/human components in it, I as the researcher will not make any judgements on the scenario being studied. With this stance, it dictates that the researcher is confound in data collection and interpretation through objective, quantifiable observations that eventually lead to statistical analysis.

In the same light, Collin (2011) perceives that positivism, as a philosophy comprises "discrete, observable elements and events that interact in an observable, determined and regular manner" (p.38).

3.2 Research Methodology

Research methodology is a systematic guideline by which the researcher will approach this study by explaining and describing procedures towards achieving reliable research outcomes. The following sections thereafter present the research strategy, approaches, methods and techniques that have been considered appropriate and the reasons why they have been selected for this study.

3.3 Research Strategy

A great number of research methodologies have been distinguished. Galliers (1991) lists fourteen whilst a hierarchical taxonomy of three levels and eighteen categories have been listed by Alavi and Carlson (1992). However, for this study, a secondary analysis of existing data will be used. The procedures employed in conducting this secondary analysis are detailed subsequently on expanding on its finer description, outlining the history of secondary analysis and its use in quantitative studies.

3.3.1 Understanding Secondary Analysis

Secondary analysis of data is a method in which data collected in another study is used to answer new research questions (Windle, 2010). Glass (2014) states that the re-analysis of this data for the purpose of answering new questions can be obtained with the use better statistical techniques that may have not been applied in the primary study. Secondary analysis is an important feature of the research and evaluation because the data can be examined to answer a research question other than the question(s) for which the data was initially collected. This method of research is useful for researchers who are looking to develop questions appropriate for analysis through existing data. There are large national datum bases available to the public that can be used by investigators to analyse new research questions (Coyer, 2005)

Secondary analysis has a long history, but the term '*secondary analysis*' originated in the 1940s and 1950s, when data from large random-sample opinion polls had more data available than was reported (Cherlin, 1991).

Secondary analysis of quantitative data became possible with the development of the computer in the 1950s and 1960s. The use of computers automatically resulted in

data that could be stored in a form that was compact and readily portable, and, of greatest importance, the information could be anonymized so that they could be used by others without revealing identification (Windle, 2010). Alongside the computerization era came the development of computer packages such as SPSS (Statistical Package for the Social Science) for statistical analysis which opened the way for easier and more sophisticated analysis of gathered data by many more people than had ever before been possible (Dale, 2004). A reactive response to these developments resulted in creation of data archives which were established for the deposition, cataloguing, storage, and dissemination of machine-readable data (Windle, 2010). Since this time, the number of users, as well as the number of studies deposited, has grown exponentially and still is; with the much easier access to the internet allowing universal access to these data sets (Coyer and Gallo, 2005). Coyer and Gallo continually assert that the use of this data that is readily accessible from large national databases or smaller local databases available from federal governments, universities, or individual researchers can be used from both quantitative and qualitative data sets to provide optimum use of the data that has been collected.

Secondary analysis may be the only means by which historical comparisons can be made, particularly where information cannot be collected retrospectively (Dale, 2004). Data archives allow the researcher to go back in time and find sources of information and further support analyses of change over time in areas such as the use of TEL in the past two decades. A majority of the data sets that the researcher came across in the data collection have been of high quality and they were summarized and described data sets related to different categories such as human infant and toddler experiments, fMRI on children and young adults, and families to guide the researcher in locating appropriate data sets for this study. The following section looks into the strengths and weaknesses of SA and thereafter methods and considerations when analysing the data.

3.3.2 Strengths of Secondary Analysis

The following Table 5 compares the strengths and weaknesses as identified by FAO, (2011):

	USING SECONDARY DATA
STRENGTHS	<ul style="list-style-type: none"> ▪ Less expensive than primary data collection. ▪ No need to set up data collection system. ▪ In many cases, quality of national surveys is high. ▪ National surveys may also provide information at sub national levels.
WEAKNESSES	<ul style="list-style-type: none"> ▪ Cannot control the timeliness of data collection and availability of datasets. ▪ Might be difficult to identify programme participants.
OPPORTUNITIES	<ul style="list-style-type: none"> ▪ Can be used to answer different set of research questions
CONSTRAINTS	<ul style="list-style-type: none"> ▪ Lack of control over data collection leads to nonspecific impact of the current study. ▪ May require statistical expertise to manipulate data and carry out analyses

Table 5: Strengths and Weaknesses of Secondary Analysis

3.3.3 Selecting the Right Data Sets

In conducting secondary analysis of existing data, the researcher must first become familiar with the nature of the data, how variables were operationally defined, and the historical social context in which the original data were collected (Rew et al., 2000). There must be congruence between the subjects from whom data were originally collected and the population to whom the new set of research questions applies.

Similar to all other methods of research, the researcher had to affirm that the data collected in the primary study was reliable and valid, reviewed the sampling procedures and operational definition of the variables, furthermore, the original studies also needed to be critiqued for any other possible flaws (Dale, 2004). Details of how these pre-cautions were taken into account are expounded later in this section under their sub-headings of *data collection* and *data analysis techniques*.

Whereas different articles and studies point out potential ways in which the secondary data can be re-used, Heaton (2008) identified six types of secondary analysis. Some of the typologies are new whilst others build on her earlier studies (Heaton, 2004). Below, in table 6, the researcher discusses the different types of secondary data analysis and identifies one that best suits this study:

SUPPLEMENTARY ANALYSIS	A more in-depth analysis of an emergent issue or aspect of the data that was not addressed or was only partially addressed in the primary study is undertaken (Heaton, 2008).
SUPRA ANALYSIS	The aims and focus is the data being re-examined in order to confirm and validate findings of a primary study (Heaton, 2008).

AMPLIFIED ANALYSIS

Where two or more datasets may be compared or combined for purposes of secondary analysis (Heaton, 2008).

Table 6: Different Types of Secondary Analysis

Following the working definitions of Heaton (2008), the researcher intends to adopt the Amplified Analysis of the data. Heaton (2004) explains two or more existing datasets may be used for comparison or to be combined for the key purpose of a secondary analysis to be carried out. This highlights the researchers' intention to compare different data from various data sets of experiments of the NG student towards developing the life stage technological model.

Primary data collection for this kind of research may provide the most direct and specific information to the research questions however it is costly and the timeline for this program does not allow for such extensive experiments to be carried out. It also supports that secondary analysis is the best option to carry out this study, Secondary analysis is the most efficient because data collection is often the most time consuming and expensive component of the research process (Glass, 2014). For this study in particular, good quality data have already been collected, so it may not be necessary to duplicate the effort. Further limitations of secondary analysis will be discussed in the 'limitations' sub-section detailing other challenges of the study as well but the next section discusses the purpose of this research.

3.4 Purpose of Research

Davies (2006) posits that there are three approaches to research; exploratory, descriptive, and explanatory. In exploratory; this is where a researcher has an idea or has observed something and seeks to understand more about it; descriptive research is trying to describe what is happening in more detail while providing additional information about a phenomena and Explanatory is an attempt to connect ideas to understand cause and effect.

An exploratory approach will be adapted due to its methodological style that is primarily concerned with discovery and generating or building of a theory (Davies, 2006). Nandhini (2013) further defines this research approach as one that is conducted towards a problem that has not been clearly defined and often relies on secondary research that will be performed through a comprehensive literature review. This approach is ideal for the study as it offers new angles to view the stated problem from both the theoretical perspective and from measurable elements. Also, this method permits room for reviewing of secondary research which is the backbone of this study's data source. In the following segment, the research strategy of this study is explained and the objectives are clearly defined.

3.5 RESEARCH APPROACH

In research, there has been reference to two broad methods of approaching research known as the deductive and inductive approaches. Deductive reasoning works from the more general to the more specific. Sometimes this is informally called a "top-down" approach where it begins with a theory and aims to test and confirm the stated theory. Inductive approach is concerned with the generation of new theories emerging from the collected data (Fereday, 2008).

For the purpose of this research, a deductive approach was used. The use of a deductive approach is suitable because this research is not looking to generate a theory from the ground up but in its stead, the nature of this study aligns itself where the theories to be used will be rationally connected to the evidence to prove the phenomena.

3.6 RESEARCH INSTRUMENT

3.6.1 Data Collection

Secondary data can embrace a whole spectrum of empirical forms, they include a wide array of data generated through systematic reviews as well as findings from a large scale dataset such as a national census or an international survey. Secondary analysis also allows the researcher to circumvent data collection problems and further allows an inclusion of a more diverse sample (FAO, 2011). This translates to having more than one study that can be combined for more statistical analysis and comparisons.

The first step in the data collection process was to identify potential datasets. The researcher began by looking for national and wide surveys that have been carried out by government institutions, first points of contact were government departments and statistical agencies. Government surveys were chosen as the first option because they provide data with particular features that have proven to be difficult to obtain through other means. These data sets are mostly nationally representative; with large sample sizes and most important of all, they are carried out by permanent staff with considerable expertise in sampling, questionnaire design, fieldwork, and all other aspects of survey work (Dale, 2004). The result is that these studies provide data of great range and quality that are well beyond the funding available to most academic researchers (Leppin et al., 2014).

Census and survey information, once located, became a challenge to access because they needed to be obtained through inter agency exchanges or requested on behalf of the researcher by the government of South Africa. The application process to the ethics committee that is the latter forwarded to the ministry then later sent to the exchanging government after approval was going to be time consuming and not feasible to this cross-sectional study.

The Second option was other appropriate datasets identified from a number of sources such as NGOs, universities or research institutes and electronic databases. After three sessions of inquiry with an experienced research librarian, the researcher engaged with the search strategy of using *Keywords* and *Boolean Operators*.

As defined in the Oxford dictionary of 2014, a keyword is 'a word used in an information retrieval system to indicate the content of a document.' Keywords form part of a Web page's metadata and help search engines match a page to with an appropriate search query. On the other hand, Boolean operators are simple conjunction words used to combine or exclude keywords in a search resulting in more focused and refined results (Muller, 2013). These conjunction words are 'AND, OR, NOT or AND NOT' using these operators can greatly reduce or expand the amount of records returned. A lot of time was saved by the use of Boolean operators as they are useful for more 'on-target' results that are more appropriate and at the same time eliminating unsuitable or inappropriate hits. Shortly below, the use of the Boolean words are explained in detail.

AND— requires both terms to be in each item returned. If one term is contained in the document and the other is not, the item is not included in the resulting list thus narrowing down the results. Figure 9 illustrates this Boolean with the dark centre representing the results obtained:

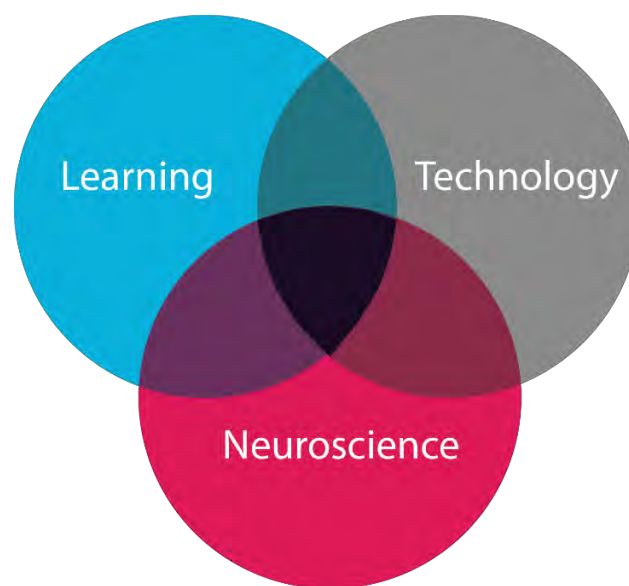


Figure 9: AND Boolean Return

OR— either term (or both) will be in the returned document broadening the search as shown in Figure 10 below.

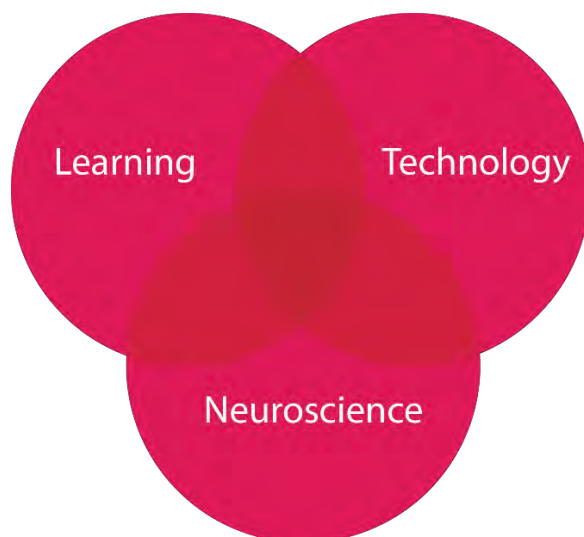


Figure 10: OR Boolean Return

NOT or AND NOT (dependent upon the coding of the database's search engine)—the first term is searched, then any records containing the term after the operators are subtracted from the results. This Boolean is completely exclusive to specific results and inappropriate use may filter out good data.

This search strategy varied depending on the database; database collections use Boolean operators in a slightly different way and those that required more specific phrases were found in the specific database's help screen. Electronic searches were performed via the following databases: WorldCat, eLIFE, PLoS, OMEGA, ScienceDirect, PubMed, Scopus, Digital Dissertations on ProQuest, EBSCO CINAHL, Ovid MEDLINE, Ovid EMBASE, Ovid Cochrane Library, Web of Science, WHO and Ovid PsycINFO. Web searches were performed with Google and Bing search engines. The researcher also conducted hand searches of bibliographies. The Keywords that were used are:

- Neuroscience AND Multimedia
- Neuroscience AND Learning AND educational Technology
- Brain experiments AND Infants
- Neuroscience Experiments AND Young Adults
- Brain experiments AND educational Technology

Bespoke to this research, each study had to meet the following criteria for the dataset to be included in the secondary analysis:

- ✓ A study had to involve the use of multimedia as defined in this research (including video games, virtual learning environments, simulations), with face-to-face interaction with the mode of instruction
- ✓ It had to involve a NG subject also as defined earlier in the literature review and they had to be born within the bracket years of - All levels of learners from kindergarteners to adults, whether involved in informal schooling or professional training, were admissible.
- ✓ It had to use non-invasive, real time brain mapping of neural activity as the learner engaged with the multimedia. Use of MRI scans that prohibited mobility of the learner towards engaging with the multimedia were excluded.
- ✓ It had to report measured outcomes for both experimental and control groups. Studies with insufficient data for effect size calculations e.g., with means but no standard deviations, inferential statistics, or sample size) were excluded.
- ✓ It had to use either similar or comparable outcome measures. If a study indicated that conclusions were drawn without any neural activity evidence, it was excluded.
- ✓ It had to be publicly available or archived with possible request options.
- ✓ It had to include at least one achievement, physical brain growth, attitude, or retention outcome measure.
- ✓ It had to be published or presented no earlier than 1985 and no later than April of 2015. It had to include outcome measures that were the same or comparable. If the study explicitly indicated that different exams were used for the experimental and control groups, the study was excluded.
- ✓ It had to include only the published source when data about a particular study were available from different sources (e.g., journal article and dissertation). Additional data from the other source were used only to make coding study features more detailed and accurate.

3.6.2 Outcomes of the Searches

After performing a number of searches, the successful ones were recorded and Figure 11 shows the order in which the data was filtered down to the desired studies. Response from the brain imaging data centres is attached on Appendix A.

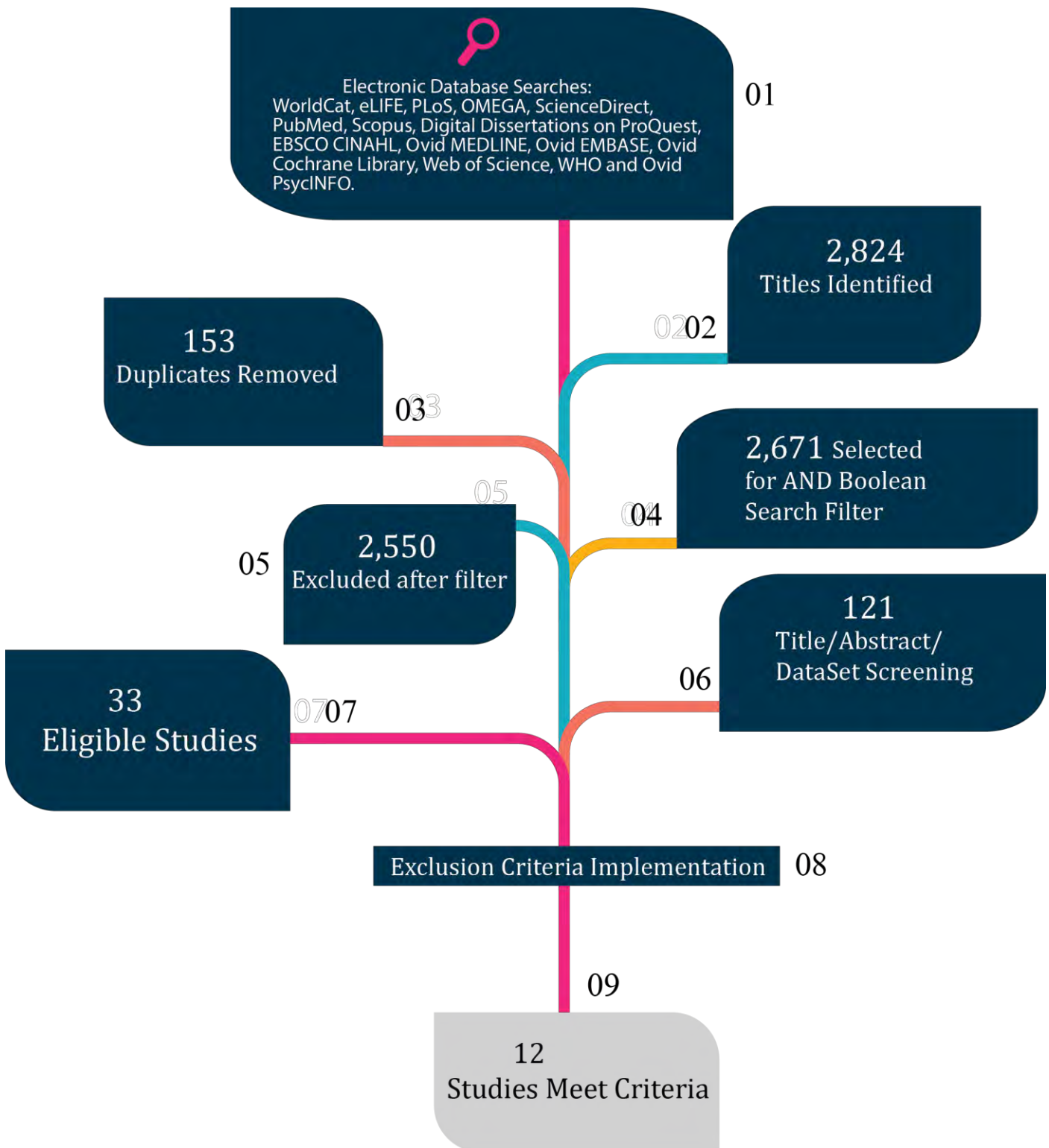


Figure 11: Outcome of Searches

3.6.3 Data Analysis Techniques

At this juncture, the researcher aims to analyse high quality secondary data by analysing the datasets through various statistical methods. Secondary analysis of data is the use of existing data to find answers to research questions that differ from the questions asked in the original research (Hinds et al, 1997). Secondary Data Analysis has been settled for as the trunk method of conducting this study majorly because of the expense that would go into carrying out the neuroscience experiments and also the participators may be what Ocepek et al. (2013) has termed as an ‘elusive population’; one that is challenging to access.

A clear assessment was made regarding the quality of the datasets selected and whether the primary dataset has the potential to answer the questions of the secondary research. Primarily, this involved a sound approach to conceptualizing the problem to be studied and working with the stated theoretical framework. Thereafter an interplay with the data to recast the research questions to fit the collected data, and this led to devising new coding systems, recoding the data to fit with the new research questions, and applying rigorous analysis to answer the questions (Rew et al., 2000).

To certify that the secondary data collected is valid for this research, the researchers assessment should increase and only consider collecting data that only provides ‘appropriate depth’ and ‘pertinent detail’ (Hinds et al, 1997:412) or as Charmaz (2006, p.18) states “data that is suitable and sufficient” in relation to the substantive area of the mentioned interest of this study (Charmaz, 2006).

3.6.3.1 Sorting

Sorting may be applied for different reasons such as: separating quantitative data from qualitative data; sorting interview data from observational data sorting to focus on one type of data; sorting to identify a sub-sample of the primary participant population or so that analysis can be selectively limited to specific themes or topics (Long-Sutehall, 2010).

All the data from the gathered datasets were transferred to Microsoft's Office Excel 2013. Before the data could be analysed the data needed to be cleaned and sorted into

different age groups that correspond to Piaget's theory of cognitive development, also grouping into the different multimedia modes that were used in the studies and the measurable outcome measures. For the outcome measures, the researcher chose not to use rigid definitions but in its stead use general descriptions. Student engagement proved to be more subjective and not as quantifiable due to the different technologies that were adapted in each test therefore grouped as expressions of satisfaction. Thereafter, for the retention results were the percentage that remembered majority of the content that was shown to them with the use of various MT. Lastly, neuro-imaging results were through observations of the brain scans and the increase in size of the areas that are active when engaged in learning. This was determined by different colour codes that light up when different parts of the brain are engaged.

Executing quantitative analysis on data Bhattacharjee (2012) put forth that it usually consists of two main methods: Inferential statistics and descriptive statistics. In order to give general descriptions and properties of the data and the variables therein, descriptive statistics will be used. This is also guarantees that no anomalies were missed earlier on during the sorting phase of the data as they would reflect in this stage of statistical analysis. Inferential statistical executions was conducted to draw up a conclusion reached on the basis of evidence and to finally test the hypothesis.

After sorting the datasets, the next step was coding the data.

3.6.3.2 Coding

After the sorting was complete, this section describes how the coding of the data was carried out.

Coding is an analytical process in which data, in quantitative form (as was received in the datasets) are categorized to facilitate analysis. Bernard (2009) concisely states that analysis is the search for patterns in data and for ideas that help explain why those patterns are there in the first place. According to Bourque and Lockyer (2004), the ideal time to code is when generating a theory (inductive) where categories and codes are generated after examining the collected data. Furthermore, coding facilitates the organization, retrieval, and interpretation of data and leads to

conclusions on the basis of that interpretation (Bernard & Ryan, 2009). For this purpose, a further elaboration on coding is given below.

3.6.3.3 Levels of Coding

Krippendorff (2011) expounds on three different levels of coding that are believed to be different levels that a coder goes through in order to get the best possible codes for the data in use. Open coding; this first level consists of nominal data, this is data that has no logical order and the classification of it is very basic. At this stage, there will be a break down, comparison and categorization of the collected data. Axial coding; the data at this stage is termed as ordinal data, one that has logical order but the differences between values are not constant. Axial level of coding is where connections between categories are made after the open coding. Selective coding; after the data has been sifted and gone through the steps above, very same data is now interval data. This means that the data has taken form and is sinuous, has a logical order, the data has standardized differences between values.

The final codebook included the following categories of study features: outcome features (e.g., outcome measure source) media and delivery, methodology features course design (e.g., systematic instructional design procedures used) demographic (e.g., stage of cognitive development), pedagogy and related fMRI scans.

Of major interest in the analysis in the data were the fMRI scans outcomes related to engagement of the MTs and delivery that also led to change in characteristics with the outcome features. In order to guide the coding process and to make it as efficient as possible, elaborate operational descriptions were developed for each item.

3.6.3.4 Active Coding Definitions

A step further into the coding was the introduction of definitions of *greater than*, *equal to* and *less than*. “Greater than” was defined as 66% or more, “equal to” as 34% to 65%, and “less than” as 33% or less. This allowed for a comparison between an overall improved learning outcome and a control outcome within each coded item, allowing the researcher to quantify the core aspects of study features (i.e., brain effects, pedagogy, and the MT). As well, this form of coding enabled the researcher to estimate

the state of the datasets from a quality perspective. Each study was coded independently in separate rooms (Khwaja et al., 2002).

Thus, the researcher believes that this Secondary Data Analysis would finally give an answer to address the longstanding controversy regarding the effects of technology, multimedia and pedagogy with empirical evidence of an engaged brain with these very technologies.

Towards the end of the summarising of the coded data, a mini meta-analysis was performed. This refers to a quantitative combination of the statistical information from the multiple studies of a given phenomenon (Church, 2002). It provided a rigorous way to summarize the results of these studies consequently contributing to the life stage technology model that is intended to be developed at the end of this study.

3.6.4 Timeline

The time frame of this research is cross-sectional in nature. Lee (1994) terms cross-sectional studies as those that are carried out at one point in time or over a short period used to estimate the prevalence of interest for a given population or a representative subset; while a longitudinal time dimension involves collecting data over a long time period (usually years) to study a phenomenon (Sekaran, 2003). To echo Lee, this study is concerned with gaining understanding from present occurrences and present time (Saunders et al., 2009) and is also deemed appropriate because of the amount of time given to complete the Master's program at the University of Cape Town.

3.6.5 Ethics and Confidentiality

Similar to all research studies, secondary data analysis requires attention to ethical concerns. In line with the ethical requirements, a filled copy of the ethics application form was sent to the ethics committee of the University of Cape Town. After the approval was obtained to conduct the study, it was mandatory for the researcher to follow the necessary procedures in conducting the research.

Authors in the area of secondary data analysis highlight issues of ethics such as copyright, informed consent, confidentiality and ownership of data (Andrews, 2012).

According to Busse (2010), there are a number of confidentiality issues in relation to secondary data that this study took into consideration including anonymizing the data, restricting the geographical area to a level that will not allow identification, and suppressing any peculiar or unusual characteristics that would allow a respondent to be uniquely identified. Below is a small description of the majorly cited issues that need to be adhered to especially in Secondary Data Analysis:

Reporting of original and secondary data analysis; Study design, methods and issues involved are reported in full. Ideally this should include an outline of the original study and data collection procedures, together with a description of the processes involved in categorising and summarising the data for the secondary analysis, as well as an account of how methodological and ethical considerations were addressed.

Ensuring original consent in the primary study; Whether conducting secondary analysis in an independent capacity or not, some form of contractual agreement between the secondary analyst and the primary researcher(s), data archive managers, and colleagues involved in the primary research but not in the secondary analysis may have to be negotiated. Informed consent cannot be presumed given that it is was not feasible to seek additional consent, a professional judgement was made about whether re-use of the data violated the stipulated contract made between subjects and the primary researchers.

Subjects remain Anonymous; where sensitive data is involved, informed consent cannot be presumed. Research participants' names may be unavailable because of confidentiality agreements in the primary study; in addition, subjects may have moved or died since they were involved in the primary research and thus the anonymity of the subject should remain (Dale, 2004).

Sharing of the Data; a related concern is whether the sharing of data violates prior agreements concerning the confidentiality of the information.

Reporting of original and secondary data analysis; such is the complexity of secondary analysis, that it is particularly important that the study design, methods and issues involved are reported in full. Ideally this should include an outline of the original study and data collection procedures, together with a description of the processes

involved in categorising and summarising the data for the secondary analysis, as well as an account of how methodological and ethical considerations were addressed (Busse, 2010).

Devaluation; to effect and deduce the data without rendering it bare; these steps were considered at every stage of the analysis. Not only so, but action in accordance with the laws on copyright and data protection were adhered to and approved by the University's ethics committee (Backhouse, 2000; Parry & Mauthner, 2004; Thorne, 1994)

Finally, the researcher was able to determine what type of permission was needed to access and use the data sets and what costs, if any, were incurred to obtain the data (Andrews, 2012). Shown in Appendix A is permission granted to access a data library of neuro-images from the OMEGA database.

3.7 Summary of the Chapter

The chief aim of this study was to develop a life stage technology model that in turn enhances learning for a NG student. Towards this objective, this chapter has sort to inform on the research design and methodology used in this research; not neglecting the philosophical underpinnings that influenced the choice of research paradigms, methods and techniques adopted in this study. The table below shows a summary of what has been discussed in this chapter:

METHODOLOGY	APPROACH
Philosophy	Positivist
Research Strategy	Secondary Analysis
Research Purpose	Exploratory
Data Collection Methods	Online Datasets

Data Analysis	Statistica Analytical Software, MS Excel 2013
Time Frame	Cross-Sectional

Table 7: Summary of Research Design

CHAPTER 4

ANALYSIS, FINDINGS AND DISCUSSION

4.0 ANALYSIS, FINDINGS AND DISCUSSIONS

After discussing the overview of the research design and methods that have been applied for this study, this chapter presents the findings of the Secondary Data Analysis and discussions of these findings.

4.1 Introduction

This study primarily sought to identify the key triggers in multimedia that enhance the brain to learn more efficiently by using real time neuroscience experiments. Along with this objective, the secondary objective was to develop a framework that would develop a model that can bridge technology, learning and neuroscience. The dearth of studies that have tested learning outcomes seem to mirror each other in their findings but without the empirical link of brain mapping evidence. For this purpose, research questions and propositions were formulated that guided the Secondary Data Analysis in testing and seeking to understand the most effective means of teaching to a NG.

The main techniques that was used to analyse the SECONDARY DATA were all quantitative, in running statistical tests to get descriptive nature of the data. This involved checking and testing the data for validity and reliability, aggregating effect sizes, testing the homogeneity assumption and regression modelling of learning features to explore the variability in effect sizes in relation to method and demographic. INSERT Brain Scans

4.2 Reliability of the Datasets

This study primarily sought to identify the key triggers in multimedia that enhance the brain to learn more efficiently by using real time neuroscience experiments. Along with this objective, the secondary was to develop a framework that would at long last develop a framework that can bridge Technology, learning and neuroscience. The dearth of studies that have tested learning outcomes seem to mirror each other in their findings but without the empirical link of brain mapping evidence. For this purpose, research questions and propositions were formulated that guided the Secondary Data Analysis in testing and seeking to understand the most effective means of teaching to the NG.

The main techniques that was used to analyse the Secondary Data were all quantitative, in running statistical tests to get descriptive nature of the data. This involved checking and testing the data for validity, reliability and performing statistical analyses on the data. Testing the hypotheses and their assumptions through mathematical equations and correlation of learning features in relation to method and demographic.

The Cronbach's alpha test was used to test the internal consistencies of variables used to measure each outcome. The Alpha was developed by Lee Cronbach in 1951 to provide a measure of internal consistency of a test or scale; Internal consistency describes the extent to which all the items in a test measure the same concept or construct and is expressed as a number between 0 and 1 (Tavakol, 2011). Tavakol further expresses that there are different acceptable values of alpha ranging from 0.70 to 0.95 however a threshold of 0.60 in an exploratory research is regarded as reliable (Tavakol, 2011).

To test the reliability of the data, the researcher intends to use two techniques to achieve this. Reliability in this study refers to the consistency and stability in the results of the tests or interviews that were conducted in the primary data collection. These tests will be carried out using Statistica, a data analysis software available at the Information Systems Lab and a software the researcher is well versed in. The first method to be used will be the Cronbach alpha, the alpha value determines the internal consistency or average correlation of items in the survey instrument that was primarily used to gauge its reliability.

The second method to be used to test the reliability of the data is Split-Half analysis. In split-half test of reliability, the data that purports to measure the same construct are randomly divided into two sets and each set is measured on its own. For a reliable full set of data, both random halves should have an alpha result that is above the 'reliable threshold' (Tavakol, 2011).

As literature shows that researchers have previously re-used a complete primary dataset for their secondary analysis (Heaton, 2008). Secondary analysis was the

researcher's final option only after careful consideration and investigation of the resources available to the researcher to carry out experiments to obtain primary data.

4.3 Data Analysis within the PTCD Stages

In this Secondary Data Analysis, it was necessary that the researcher conduct a thorough review of the literatures of where the data sets were retrieved so as to ensure that the proposed questions have not been answered. The order of the secondary analysis that will be followed in this section is shown in the Table 8 below:

ANALYSIS ONE	ANALYSIS TWO	ANALYSIS THREE
INFANTS	CHILDREN	YOUNG ADULTS
Hypothesis: “ Their predominant learning style is majorly of feeling, touching and handling.”	Hypothesis: “ Their ability to learn is directly proportional to their cortical thickness.”	Hypothesis: “ The Class with TEL had a higher learning achievement than the one without.”

Table 8: Order of Secondary Analysis

Piaget’s theory of cognitive development distinguishes four primary cognitive structures that correspond to four stages of development (Huitt & Hummel, 2003). These stages are what have anchored this study as it seeks to understand the neuroscientific foundations of learning.

The subsequent section delves into the SA as shown in the Table above. The findings of these analyses are paramount towards developing the life stage technology model.

4.4 ANALYSIS ONE

In this first analysis, the researcher focuses on the infants of the NG. The infants in this analysis range between the ages 0 – 2 years. Piaget posited that the infants at this age are predominantly concrete and active in their learning style and that learning here is predominantly through feeling, touching and handling (Huitt & Hummel, 2003).

Parents are now exposing infants to early screen media and increasingly using technologies such as computers, tablets, television and games as a means of teaching (Zack, Barr & Gerhardstein, 2009). The two Primary studies that were analysed in this section are from Zack et al. (2009) and Mash, Bornstein & Arterberry (2013). These two datasets both with online open access allowed the researcher to retrieve the data and to perform statistical analyses on both towards this analysis.

4.4.1 The study

In this first structural study, the experiment looks at the feasibility of imitation from 2D to 3D surfaces and transfer across dimensions using touch screen technology. As stated in the primary study (Zack et al., 2009), the main objectives were to " (a) to obtain the baseline rate of button pushing for the 2D touch screen and 3D objects; (b) to establish whether infants would imitate the target actions on the 2D touch screen and the 3D object; and (c) to test whether infants would imitate across dimension." The main objective for SA of this dataset was to determine whether the use of technology was effective towards improving the infants' interpretation of their surrounding testing the theory that the infants are predominantly active in their learning styles.

4.4.2 Stated Procedure

In the primary study, the procedure of the experiments was explained to the caregivers and "they were instructed not to name the object or the sound it makes, or to point out anything on the stimulus, including the button. Caregivers were permitted to respond to what their infant was interested in (e.g. you're touching the eyes), to say neutral phrases (e.g. look at that) or to offer encouragement if the infant responded correctly (e.g. good job) during the test phase. A second experimenter videotaped the session from a side angle, such that both the infant and the object/touch screen were

visible. All phases of the experiment were videotaped for later analysis. Infants were primarily visited in their homes; however a small subset of participants (N=6) were tested in a child care centre. All participants were tested in a single session." (Zack et al., 2009:p.8)

4.4.3 Ethical Considerations

An experimenter described the study to and obtained a signed consent from the caregivers of the infants after a thorough explanation of the test and study being carried out (Zack et al., 2009).

For this secondary analysis, measures taken were:

- Working from an approved consent from the university ethics committee,
- Ensuring that there was original consent in the primary study and
- Thereafter anonymizing the data.

These were the steps taken to ensure that no issues of ethics were overlooked.

4.4.4 Demographics of the Participants

Seventy-two 15- to 16-month-old (26 male, 46 female) full-term healthy infants and their parents were recruited through commercially available records, child care centres, and by word of mouth in the DC metro areas.

The gender distribution of the infants that participated can be seen in Table 9 below:

GENDER	FREQUENCY	PERCENTAGE
FEMALE	46	63.8
MALE	26	36.2

Table 9: Gender Distribution

AGE (days)	
MEAN	476.2
SD.	19.0

Table 10: Mean Age (Days)

As shown from the table above, the average age of the infants is 476 days. This means that all the infants can be classified as a NG student born within the stipulated years as defined by Roodt (2013). The race of the infants are also shown in the Table 11 below:

RACE	FREQUENCY
AFRICAN AMERICAN	1
ASIAN	1
CAUCASIAN	66
MIXED DESCENT	3
UNREPORTED	1

Table 11: Race Categories

As can be seen in the table above, Caucasian is the most represented race (91.6%) followed by Mixed Descent (4.2%) and an equal representation of African American, Asian and Unreported (1.4%). The reason as to why there is an unreported race was not highlighted in the literature of the primary study.

4.4.5 Coding and Reliability

A codebook was created under the three main dimensions (constructs) that were being tested. The coding technique was maintained from the primary study which was 'an imitation score of '0' was given the infant did not press the button within 30 seconds from time of first touch or a '1' if the infant did press the button within 30 seconds.' Under each dimension were the imitation scores grouped under, as opposed to the initial study.

In the primary study, exclusions were made to the sample to ensure more reliable results at the end of the tests. A total of 7 infants were excluded from the final sample due to:

ERROR	NUMBER OF INFANTS EXCLUDED
The Primary Researchers Errors	3
Where Parents Interfered	1
Lack Of Response	3

Table 12: Exclusion Criteria

Measures taken in this Secondary Analysis was running a reliability test using the split-half analysis technique. In split-half testing, reliability is confirmed by observing the coefficient alpha results which directly tests the correlation of the two halves being measured. The researcher randomly divided all the variables that purport to measure the same dimension into two sets and randomly ran the split half analysis. The reliability estimate, is the correlation between these two total scores as shown in the Table 13 below. By looking at the coefficient alpha results, the split-half analysis confirms the data to be reliable as it is above the .70 mark of reliability.

Cronbach Alpha, Full Scale: .8024		
N=72	SUMMARY OF 1 ST HALF	SUMMARY OF 2 ND HALF
No. of Items	36	36
Mean	238.81	235.14
Sum	3785.00	3363.00
Std. Dv	9.50	9.894
Variance	72.33	97.90
Alpha	.72	.80

Table 13: Split Half Analysis Results

4.4.6 Hypothesis

The analysis of this dataset is to confirm the following hypothesis:

“Their predominant learning style is majorly of feeling, touching and handling”

The use of a One-way ANOVA test will be used.

4.4.7 Results of the Analysis

A One-way ANOVA test confirmed this hypothesis revealing a main effect of condition, $p < .002$, with a partial $\eta^2 = .68$ indicating that the infants within the same dimension groups 2D/2D and 3D/3D performed significantly better than the cross-dimension groups. The Mean imitation scores across dimensions 2D/3D establishes that infants can imitate the target actions from the touch screen to the live 3D model. Notably, both cross-dimension groups performed worse than the groups within the same dimension. The results of the cross-dimension group only support what Marno and Csibra (2015) report as video deficit effect. The video deficit effect was coined after empirical research demonstrated that infants, toddlers and pre-school children learn less from television and 2D images than from live face-to-face interactions (Marno & Csibra, 2015). Thus, the infants had to generalize what they saw on the touch screen to the 3D model and this was done poorly due to cognitive overload in an already challenging task (Green & Bavelier, 2012). An additional chi-square test to examine whether ostensive direction given by the experimenter in the primary study has any effect on the transfer success from the touch screen to the 3D object. This also shows that ostensivity did not facilitate any transfer of imitation or influence their initial intention. The researcher then argues that learning, as pointing to what may seem as a corresponding object or an image, is a less demanding task than showing its functional equivalence.

From a practical point of view, cognitive neuroscience has demonstrated that infants possess different event-related potential responses to 3D objects and their representation in 2D form. The neural response of the familiar 3D object to its still image representation occurs significantly faster (Zack et al., 2013). It is fair to note that the infants did well in imitating within the same dimension of 2D/2D as they did in 3D/3D and the tests show that they didn't have problems in imitating the images.

In further studies conducted by Meltzoff et al. (2013), infants' recognition of familiar 2D representation using event related potentials have proven that neural signatures occur much faster in the infants brain than it would with an unfamiliar 2D representation. Infant recognition memory research is carried out using still images because more challenging verbal cues are not feasible since the infants are unable to respond verbally (Carver et al., 2006). This second study that was selected for this analysis was to illuminate on the neural bases of how infants recognize familiar faces when shown pictures of their mothers and female strangers. This is ultimately to test whether familiar objects, as represented in either 2D or 3D, cause an organized series of brain activity that can be linked to development of a memory brain system. Developmental cognitive neuroscience research has demonstrated that infants have different event-related potential (ERP) responses to real-world objects and 2D representations of them – the neural signature for recognition of familiar versus novel objects (e.g., a favourite toy) occurs significantly faster when the objects are presented in 3D than when presented in 2D (Carver, Meltzoff & Dawson, 2006). This provides converging support for the idea that there is an added task difficulty involved in mapping from 3D objects to their corresponding 2D representations.

A plethora of computer games, new media and gadgets developed are out there for infants to ingest and hopefully learn from. Inasmuch as there is growing empirical studies showing the effectiveness of these modes, this study is aimed at guiding learning that can be translated to real-world actions. This study offers to play a role in narrowing down this critical gap for the people who want to design these MTs and their use for effective teaching. To sum it up, this analysis has proven to be consistent with the primary results in proving the hypothesis to be true in support of learning mostly through touch, feeling and handling.

4.5 ANALYSIS TWO

For this dataset, the researcher intends to run analyses continually testing the hypothesis of cognitive development with the aid of neuroscience experiments. The following study primarily aimed in finding the positive association between cognitive ability and cortical thickness.

4.5.1 Stated Procedure

The initial intention of the primary study was to correlate the thickness in different brain regions over time with the g-factor. The g-factor is used to measure general intelligence on the premise that performance across various brain regions tend to be positively related. Various studies have indicated that cognitive ability is related to regional brain structure (Winkler et al., 2010). Furthermore, a recent meta-analysis points out that a network of multimodal association areas in the brain are highly correlated biochemically, structurally and functionally towards intellectual abilities (Winkler et al., 2010).

The researcher aimed to characterize brain regions where cortical thickness was associated with cognitive ability differences and to test the hypothesis that these regions are mostly located in multimodal association areas.

Being aware of the fact that the researcher is not well versed in reading and interpreting of brain scans T1- and T2-weighted images. The scans were inspected by two experienced neuro-radiologists at the health sciences department, University of Cape Town. The inspected scans are attached in Appendix

MRI scanners used were 3D 1.5 T from Siemens Medical Systems (Siemens) with 1mm isotropic data acquired sagittally from the entire head. Total acquisition time was 25 minutes although there was a fall back plan for the participants who could not tolerate this process; a use of shorter 2D scans were used. All images were subjected to CIVET Pipeline software version 1.1.9 for fully structural image rendering (Karama et al., 2009).

4.5.2 Ethical Considerations

In the Primary study, that the primary caregiver of the children gave consent to the participation of the children.

In this analysis,

- There was no bio-data present of the participants of the primary study for the data was already coded; automatically declaring it random.
- Working from an approved consent from the university ethics committee
- The brain scans analysed are attached on Appendix B of this dissertation

4.5.3 Demographics of the Participants

Out of a healthy sample of 433 participants, 33 were within the age bracket limit of 11 years that this study was interested in.

GENDER	PERCENTAGE
FEMALE	51.3
MALE	48.7

Table 14: Gender Distribution

AGE (Years)	
MEAN	9.8
SD.	0.03

Table 15: Mean Age

4.5.4 Reliability and Validity

The list below shows the exclusion criteria that was used in selecting the final participants that were finally used for the primary study:

- Children of parents with limited English proficiency. Adopted children excluded due to inadequate family histories.
- Current or past treatment for language disorder; a lifetime history of psychiatric disorder
- History of inherited neurological disorder; history of mental retardation due to non-traumatic events in any first-degree relative; one or more first-degree
- Abnormality on neurological examination

4.5.5 Data Analysis and Discussion

An analysis of two-sample t-tests was run assessing intergroup demographic differences. With a probability value of 0.05. There were no significant differences in distributions within the group. Looking at the brain scans, the regression of the cortical thickness disclosed a directly proportional relationship of cortical thickness and the g factor. Regions with this stated relationship were mostly visible in the multimodal association areas. Distributed models of intelligence also famously known as P-FIT model by Jung et al. (2007) are consistent with the findings of this study. However, the stated P-FIT model failed to show what is evident here, is that the medial parietal lobe and the dorsomedial prefrontal cortex have been highly observed to be important areas where information from different parts of the brain converge for high-level processing and have been shown to be involved with cognitive performance.

Cortical thickness seemed to differ between the two different scanners of those who were incapable of sitting through the whole process vis a vis those who did. However, holding down the threshold at 0.2 ended up revealing a similar picture. Similarly, the areas of high association of cognitive capabilities and cortical thickness were in three of the same parts. (Lateral prefrontal, occipital extrastriate, and Para hippocampal areas). The correlation that has been seen between the active networks in these regions and cortical thickness especially around the areas involved in multimodal processing is of paramount importance. This translates to links being drawn in actual mental ability in relation to the size of the cortical area. The scans also support that the size of these similar areas of cortex are the determiners in intelligence between children and adolescents.

In summary, if one is to leverage MT and facilitate for growth/expansion of the cortex areas then potentially, it increases the chances of higher multimodal capabilities. The hypotheses holds true; the cortical thickness is directly proportional to their ability to learn.

4.6 ANALYSIS THREE

In this final analysis, the use of multimedia is adopted in a classroom setting. In the literature review, multimedia learning was defined as learning that takes place with the aid of words and pictures. The words therein can be printed or on-screen or spoken. The images can be static (photographs, graphs or illustrations) or dynamic (interactive illustrations, animation or video) (Mayer and Moreno, 2010).

Over a while now, there have been suggestions that computer games or video games might be useful in formal educative contexts (Yu et al., 2014). The effectiveness of the use of games in teaching and learning has been confirmed in various studies. It has come leaps and bounds comprising reinforcements from neuroscience in brain scans indicating actual positive physical brain growth as the NG student engages in the video game (Bavelier et al., 2012).

A secondary analysis of two data sets will be analysed. The first set looks at learning achievement in relation to game-based instruction; the second analysis is of brain scans of enhanced functional connectivity in relation to action video game playing.

4.6.1 Data Set One

This dataset was obtained from a primary study which was looking at 'education related majors' performance measures with pre/post-video game practice' (Novak & Tassell, 2015). The dataset had public open access but only through a registered university of the WorldCat System.

4.6.2 The Procedure

The study was carried out in a senior high school. The collected data was used to compare two randomly selected classes. Class X was under computer game-based instruction and Class Y was non-computer game-based instruction, respectively. Class X was then trained on how to play the game and each training session lasted for six hours for a span of two days. As part of the training, the participants were introduced to the gaming goals and objectives and they were equally allowed time to practice the game and thereafter, taught on how to install, start and play the game.

Instructions in both Class X and Class Y remained the same in terms of teaching outline, materials, contents and learning objectives. However, it is worth noting that

other variables that may not be measurable in this secondary analysis may have influenced the outcome of the participants such as motivation of the participant and the instructional quality of the instructor involved. To explore the effects of the two types of instruction, there were pre-gaming and post-gaming questionnaires given out to the participants. Participants were required to answer questions based on a 5-point scale.

4.6.3 Ethical Considerations

In the primary study, all participants signed a consent form towards taking part in the study. The scores remained confidential between the documentation and the participant. Once the data was coded and the participants' names were never associated with the data again (Novak & Tassell, 2015)

In the Secondary Analysis:

- The researcher ensured that there was no bio data in the data sets as received. The data was not shared with colleagues nor classmates in any comparisons whatsoever.
- Working from an approved consent from the university ethics committee.

4.6.4 Demographics of the Participants

The participants were 103 NG students.

GENDER	FREQUENCY	PERCENTAGE
FEMALE	51	49.5
MALE	52	50.5

Table 16: Age Distribution

AGE (Years)	
MEAN	17.86
SD.	0.50

Table 17: Mean Age (Years)

4.6.5 Reliability and Validity

The instruments that were used in the primary study for mathematics assessments test have been established in numerous studies with thousands of participants (Leppink, Paas, Van der Vleuten, Van Gog & Van Merriënboer, 2013; Novak & Tassell, 2015). This is used as a reliable gauge of complex cognitive behaviour because it has been proven to strongly correlate with the working memory; which in studies of human behaviour, is a central construct (Schmader & Johns, 2003).

To further test on the reliability of the data, Table 18 shows the internal consistency computed using Cronbach's alpha coefficient.

CONSTRUCT MEASURED	CRONBACH'S ALPHA	STANDARDIZED ALPHA
PRE – GAMING SCORE	0.767	0.777
POST- GAMING SCORE	0.806	0.806

Table 18: Cronbach's Alpha

4.6.6 Hypothesis

The analysis of this dataset is to confirm the following hypothesis:

“The Class with TEL had a significantly higher learning achievement than the one without.”

4.6.7 Results and Discussion

In order to test this, the researcher ran a One-tailed Paired Difference T-test. The test is one-tailed because the test only seeks to answer if there was a positive learning experience and not about any inverse effects of the gaming experience. Table 19 below shows the results as obtained maintaining a significance level of 0.05:

CLASSES	Mean	Paired Differences		t- value
		Mean	S.D	
PRE -CLASS X	13.59	.34	5.67	.54
PRE- CLASS Y	13.19			
POST-CLASS X	18.17	1.27	6.18	2.21
POST-CLASS Y	16.89			

Table 19: Difference T- Test Results

The Secondary Analysis involved comparing Class X and Class Y instruction delivery and the level of knowledge acquired. In most institutions, modern educational technologies may involve distance learning via video conferencing, multimedia projectors, online learning environments and emails. It was expected and most normal for the students to have expressed escalated interest in learning using games. Therefore, it is highly likely that students were highly motivated when the time for engaging in the primary study came. Because the computed t-value of 2.21 is larger than .54, the hypothesis has been confirmed. The results have provided evidence that the class that used TEL obtained a significantly higher level of learning that the one that did not. The actual difference in learning achievement is 1.67, not large but statistically significant.

Cognitive engagement as stated by Finn and Zimmer (2012) is when the student, or the participants in this case, go beyond the minimal requirements to facilitate learning of complex material. Playing and the use of video games have revealed substantial

positive effects, both on behavioural and physiological (Bavelier, 2012). Seemingly more than just on retaining the learning material. In numerous settings and studies, video games have shown to have positive impacts on motor performance, cognitive performance and affect. And also a major improvement in attentional capacity, temporal resolution and useful field of vision (Lohse et al., 2013). These are transferrable skills that can be applied across different fields of life. On the other hand, no significant measures were calculated to show a difference in learning between males and females; after calculating the motivation levels of both males and females in Class X, it was expected that males, more motivated than the females, should have achieved significantly more knowledge retention than the females. Surprisingly, no major differences were noted in the learning achievement between males and females. It is possible that the females in class X may have relied more on other learning strategies such as paying extra attention to the instructor and self-education thus relying less on the computer game. The opposite may hold true for the males in Class X, having higher motivation towards the computer based instruction in, they may have over looked other learning strategies and in turn the overall learning achievement met an equilibrium resulting in similar academic results.

A conclusion was arrived; that students in Class X, under TEL, obtained greater learning achievement than those in class Y, who had the traditional mode of black-board and chalk. Participants were more motivated towards using games in learning as opposed to the old didactic way of teaching; and learning was not influenced by gender.

In the area of using games for enhancing learning, there are still countless questions unsolved (Sherry, 2013); a single game may prove to be effective in one educational field while the other may not. Leaving room for more studies to be conducted whilst more multi-modal appropriate games are awaiting development.

Milestones have been accomplished in the field of Neuroscience, directing but not limited to brain research examining the neural basis of a video gaming experience. Action video game experts were found to have enhanced functional connectivity and grey matter in their brains (Lohse et al., 2013).

The following section is a mini-secondary analysis of a neuroscience experiment of students engaging in an action video game and their brain scans were taken. The purpose for this analysis was to confirm with neural evidence the actual effects in the brain during video gaming. The researcher maintains that video game play could be an effective supplement to the traditional ways of teaching and learning.

4.6.7 Data Set Two

This sections looks at a primary study and its main objective was to examine Action-Video games' related effects on the plasticity of insular sub regions and functional networks therein (Gong et al., 2015). Neuroplasticity is the ability to alter the underlying neural structures responsible for learning whilst learning new behaviours and form new memories within an adult brain (Glass et al., 2013) and the insular sub regions are critical in attentional and sensorimotor functions (Gong et al., 2015).

The Secondary Analysis only reviews the brain scans that were openly available upon retrieval of the primary study. Requests for the primary datasets was made for further statistical analyses but a response was not received within the cross sectional time for this study. After initial contact, the cited authors of the primary study were given 10 working days to respond before a gentle-reminder-email was sent. After no response, the researcher looked for other alternatives to make contact; unsuccessful, the last email was sent to the authors before declaring them unreachable. Results of the original datasets were published however, without conducting tests of validity and reliability, the researcher avoided to draw conclusions from any statistical conclusions made in the primary study.

4.6.7.1 The Procedure

Two groups of subjects were tested: Action Video Games (AVG) experts and amateurs. The criteria for the two groups were: The experts are highly experienced AVG players had at least six years of action gaming experience and were recognised as regional or national champions. The amateurs were not regular players and only had less than one year experience. A total of 27 experts and 30 amateurs participated in the primary study. All of the subjects were right-handed according to the Edinburgh Inventory,

reported normal or corrected-to-normal vision, had normal hearing and reported no history of neurological illnesses.

4.6.7.1 Ethical Considerations

In the primary study, the study protocol was approved by the ethics research committee at the University of Electronic Science and Technology of China (UESTC) and has been performed in accordance with ethical standards outlined by the Declaration of Helsinki (Gong et al., 2015). Informed consent was obtained from all subjects.

In this SA:

- The brain data sets were randomized and did not have any bio-data attached to them other than descriptions of the scans under the test carried out on the participants.
- Working from an approved consent from the university ethics committee.
- The brain scans used in this analysis are on Appendix C

4.6.7.2 Data Acquisition

The brain images were acquired on a 3T MRI scanner (GE Discovery MR750) at the MRI research centre of UESTC.

4.6.7.3 Data Analysis

Commencing on the analysis of the scans, the assisting radiologist advised to define the regions of interest to avoid pre-conceptions. The coordinates used in the primary study were maintained which were adopted from Cauda et al. (2011) stating 20 regions of interest; the right and the left having equal numbers of 10 each. Figure 12 below shows the regions mapped out by Cauda et al. (2011):

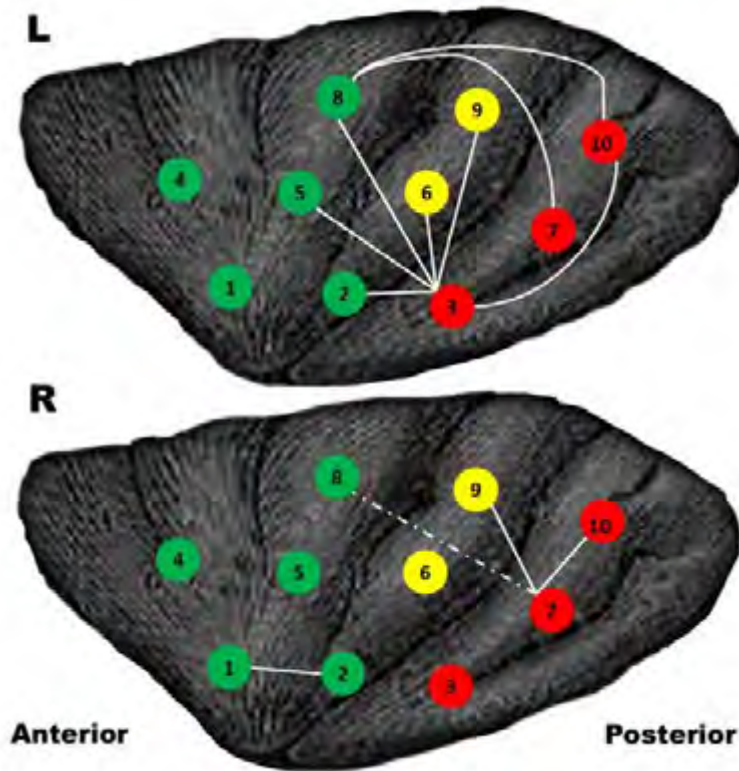


Figure 12: Areas of Interest

4.6.7.4 Discussion

To evaluate our hypothesis, simple comparisons of the brain-stain-colour coding was done comparing the two sets of groups; experts to amateurs.

Firstly, it was noted that the images of the amateurs contained distinct networks supporting findings from Caude et al.'s (2011) proposition on the anterior and posterior regions are involved in the functional networks respectively. Following, significant differences between experts and amateurs posterior regions of interests. These scans are attached on Appendix C of this study.

The above suggests that enhanced functional connectivity might have influenced the sensorimotor regions in experts. Given the results of the amateurs, the activity seen in the experts' sub regions indicate an enhanced functional integration between both attentional network and sensorimotor network improving coordination between the two areas.

The images provide converging evidence that the dominant specific regions, dependant on the test group, differed on cognitive load experienced by the amateur or expert. Particularly on the experts, of whom the researcher had hypothesized would experience less cognitive load due to their vast experience, displayed an increase in recruitment of neural areas mostly associated with working memory and increased performance in comparison to the amateurs. By comparing the two, predominantly evident was experience-based enhancement in the left insula. Functional connectivity was noted between anterior and posterior insular sub regions and furthermore integration between the attentional and sensorimotor networks.

These scans provided neural evidence that current methods for learning vary in cognitive load as they place different demands on the NG students' brain. Action video games have shown to induce neuroplasticity. As aforementioned, it is the ability to alter the underlying neural structures responsible for learning whilst learning new behaviours. Playing, therefore, demands of the player an integration between attentive and sensorimotor networks. Consequently, it may seem that certain multimodal experiences appear to engage additional cognitive resources which can result in an increase in functional connectivity expected to equate to increased learning and retention of the material. These pattern of results would have been reinforced by further statistical analyses and drawn more specific level of correlations with access to more data. No disregard was made to the fMRI images as they did show concrete evidence in immediate occurrences in the brain.

4.7 Chapter Summary

This study, through secondary analysis, has looked at four different primary studies set in different contexts and were all intended to answer different questions other than those stipulated in their primary research. Using Piaget's Theory on Cognitive development as a cursor on the different life-stages (Piaget, 1976) and the expected development that should've occurred in the brain, each analysis was aimed at ascertaining the most effective tool towards enhancing learning at each of these stages.

The first analysis showed that infants' brains are more positively stimulated towards real-life objects (3D) as opposed to 2D objects thus increasing the chances of making learning much more effective and more efficient. It was noted that at this tender age, it was cognitively challenging to transfer information across dimensions indicating that the transfer of learning from tablets, television sets or technologies alike may not be as easy as it is obviously assumed to be in the present time. Further studies are encouraged to examine an introduction of various cues whether verbal or physical to test on cognitive load and an increase on overall performance of infants. Locating and further understanding where the representation from one dimension to another breaks down will provide important information on how infants learn. More so for parents and educators, as they are served with a plethora of 'new media' designed for consumption by the infants. This information will also seal the gap for industries that intend to design and make use of these MTs as effective teaching tools.

The second set of data has shown that training with a sufficient level of simultaneous information resolute to an increase of regional cortical thickness; areas highly associated with multimodal executions in children. The results further suggest that these areas of cortex are responsible for implicit knowledge which tend to structure and propel a child's behaviour whenever in a multi-modal experience. Piaget (1976) observed that children at this age learn best through manipulation of symbols and begins to internalize actions. In line with Piaget's findings, this analysis pointed out potential links between the observed regions of engagement and key aspects of a number sense as acknowledged in the fields of neuroscience, mathematics education and developmental psychology (Piaget, 1976; Szucs et al., 2013; Baccaglini-Frank &

Maracci, 2015). Baccaglini-Frank & Maracci (2015) list these important aspects as approximate estimation of quantities, fine-motor ability and mastering basic to sophisticated counting principles. This evident link is of importance if children are to be taught more effectively. It is worthwhile to note that cortical thickness on its own is not sufficient to enhance learning (Glass et al.,2013) as a combination of instructors ability and student engagement levels play an integral role in learning as a whole (Roodt, 2013).

And lastly, the final analysis with supporting neural evidence, was able to reach a conclusion that participants using gaming aided instruction attained significantly greater learning achievement than those who did not. The researcher also noted that games may be effective in different subject areas of education and maybe even different students in different countries. Neuroscience was also able to highlight the fact that video games are capable of enhancing functional integration of regions that are associated with attentional and sensorimotor functions allowing students to not only increase their chances of learning more but also developing skills that can be applied across different fields of life. More studies are encouraged on games and learning to appropriate development and application.

The next chapter conclusively develops the life stage multi-media technology model for possible advice on the consumption for the NG.

CHAPTER 5

THE LIFE STAGE TECHNOLOGY MODEL

CHAPTER 5: LIFE STAGE TECHNOLOGY MODEL

5.1 Introduction

This research was not only based on finding out whether MTs have an effect on the brain of the NG but also aims to develop a life stage technology model that will aid in determining what technology is suitable and most effective at their different ages. This model will be developed by using relevant input from previous chapters and the findings from the analysis. This model is a synthesis from Piaget's Theory of Cognitive Development (Huitt & Hummel, 2003), Cognitive Theory of Multimedia Learning (Mayer, 2009) and findings from the Secondary Analysis. It is called The Nedunology Model. The reason behind the name is because it considers the three main elements of this study; Neuroscience, Technology and Learning. The next chapter looks at the details of the contributors towards the Nedunology model.

5.2 The Contributors

5.2.1 Piaget's Theory of Cognitive Development (PTCD)

As detailed in Chapter 2 of this dissertation, Jean Piaget was one of the most influential researchers in the area of developmental psychology. He was mainly interested in the process of children coming to know and learn and the stages they move as they gradually grow (Piaget, 1976; Huitt & Hummel, 2003).

The first column of the Nedunology model (Age Group) borrows from PTCD's identification of notable age levels where the brain was found to have critical, foundational growth that dictate how learning occurs. The researcher took to understand that at each of these different stages, the brain would then need to learn in a different way than its previous stage. PTCD was chosen because:

- PTCD has been tried and tested. The writings of Piaget (1976) in collaboration with other researchers, form the basis of the Constructivist Theory of Learning and Instruction (Neisser, 1976; Bruner, 1974; Vygotsky & Vygotsky, 1980; Dewey, 1997)

- All the age groups were represented. From infancy to adulthood making it an all-rounded reference point in regards to age.
- It offers a simple enough reference to the instructors when looking to implement the findings of this study.

5.2.3 ELT and CTML

Early into the Literature Review of this study, the researcher identified and used the ELT to understand the learning preferences of the NG. Having a grasp on their preference led the researcher to look at the impact MTs have on the students. This is due to the fact that the NG's lives are infused with technology and interactive media (Berk, 2009). CTML confirmed that the NG students are indeed different learners and that MTs have proven to teach them more effectively.

The second column of the Nedunology model (Confirmed Hypothesis) was derived from the analysis of the secondary data obtained by the researcher. The results, after statistical testing, confirmed each of the mentioned hypotheses. This column informs and guides the instructors on the learning style preference of the NG student at the particular age stage. Educators should take into account the importance of recognizing their learning styles for more effective teaching.

5.2.4 The Secondary Analysis

The results from the secondary analysis in Chapter 4, which analysed secondary data of experiments of NG students and their use of MTs in learning, was to ultimately measure the level of learning. Different Hypotheses were raised in each analysis each looking to test the integration of these MT's at different of different age groups. The results are used to populate the last column of the Nedunology model that advices on the most effective MT at each age. This advice is to support the goals of the learning programs and aid in improving the students' outcomes.

5.2.5 The Nedunology Model

The Life stage technology model, called the Nedunology model is depicted in the figure below:

AGE GROUP

CONFIRMED HYPOTHESIS

RECOMMENDED MT'S



0 - 4 YEARS

THEIR PREDOMINANT LEARNING STYLE IS MAJORLY OF FEELING, LEARNING AND TOUCHING

- Basic shapes and elements should be taught using physical objects other than digital representations.
- If the infant is distressed, an electronic toy should not be used avoiding passive screen time
- Exploration of digital materials should only provide access to images of objects familiar to their environment.



5 - 12 YEARS

ENGAGE THEIR CORTICAL BRAIN AREA FOR MORE EFFECTIVE LEARNING

- Use of multi-touch devices. This will enhance their fine-motor abilities.
- Also use real objects to master basic and complex counting principles
- Applications that develop number sense; requiring different strategies to achieve results and enhances feelings of success.



13 - ADULTS

MULTIMEDIA TECHNOLOGIES FOSTER HIGHER LEARNING ACHIEVEMENT FOR THIS AGE GROUP

- Apply a wide range of MT's on a variety of platforms. Including video games, literacy software to explore math, scientific concepts and reading.
- Video/Visual presentations with symbols attaching meanings to concepts
- Group activities that involve collaboration with case studies requiring experimentation and deductive reasoning.

5.3 Chapter Summary

The details of this chapter have shown how the Nedunology model was developed. It used inputs from previous chapters and the findings from the analysis to produce the Nedunology Model.

The model was synthesized to assist the educators and parents of the NG student in order to advise on consumption of technologies to enhance learning. Being able to model the effective use of MTs creates more opportunities for parents by empowering them in making informed choices about screen time and technology use at home (Nouchi et al., 2011).

The model was developed with results from healthy NG students and is not well rounded enough to cater for NG students with special needs and/or developmental delays.

The next and final chapter is the conclusion to this dissertation; with a summary as well as recommendations for future research to be done.

CONCLUSION

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

The previous chapter looked at the development of the Life-Stage technology model developed from the attained results of the analyses. This is the concluding chapter of this dissertation and it includes recommendations for future research.

6.1 Conclusion

This research brought together how TEL is making rapid strides in areas highly relevant to education and also highlighting on how to prepare instructors for the NG. There is a growing consensus that MT should play a more integral role in the learning process of the NG and it should not be viewed as an add-on. This study has been able to support this claim. The mere use of MTs in the class room does not directly translate into effective teaching and learning, in its stead, they should be coordinated with the training of teachers to integrate technology into their teaching so seamlessly that in the long run, it results in developed problem-solving skills, thinking creatively and profound learning that will last a lifetime (Kozma, 2007). The researcher deems these skills as essential, skills that are vital to sustain an information society and a vast knowledge economy.

This study also presented how cognitive neuro-education is a fast growing field, using neuroscience to accurately understand the blueprints of learning. In this study, it was important to understand how the NG retain memory, what key factors are related and how essential and effective the presentation material is in getting the message to the students. Insights from various researchers also showed how the NG relate to and with technology, and with it, it has brought to light how neuro-education is paving the way towards a better prepared instructor.

The findings indicate that for the NG to be able to attain the highest learning achievement, the use of MT's should be applied accordingly to the cognitive development of the student. For infants and toddlers, the assumption that using games that are 'child-like' was debunked and more physical, real-life approaches are more effective in teaching them. For young children, a balance of MT should be complemented by physical objects in developing their multi-modal capabilities and a number sense towards a genesis of logical thinking. Once this stage has passed, a wide

array of MTs are encouraged for the NG teenagers towards their adulthood. Manipulating the MT by attaching logical connotations to it and more complex learning material is easier understood through this medium. This study also found that in the event where there is wrong applications of MT, no learning is achieved and negative effects and habits are formed in the NG that constitute in slow cognitive development.

The secondary objectives were realised in this study. The researcher found that there was a significant difference in learning where there was use of MT in teaching. In the case of analysis three, class X showed higher levels of learning, engagement and motivation towards the content that they were being taught contrary to class Y. Further analysis revealed that actual physical growth and expansion of the brain occurs when engaging with certain MT like video games. This brain expansion automatically allows for skills to develop that can be applied across different areas of life. This double advantage of using MT should be leveraged as early as possible in the life of students.

The primary objective of this study was also achieved. This is the Nedunology Model; a life-stage technology model that advises on the appropriate MT to be used by the NG student in different stages of their lives. Through PTC and the analysis of the data, the researcher was able to allocate the different MTs that tested to be effective to the NG student. The Nedunology model clearly indicates what instructors should consider as they prepare their teaching material if they are improve student engagement and ultimately, learning.

6.2 Future Research

The following are mentions of further research as recommended by the researcher:

- a. A testing of the Nedunology model is mandatory in order to fine-tune it to higher levels of accuracy. Further on, it could include NG students with special needs broken down into wider categories for easier reference.
- b. A longitudinal study, as extensive as to the one mentioned in the literature review (Dahlstrom et al., 2012), where a NG is monitored from infancy to adulthood exposed to the recommended MT and their cognitive development

is tested at each stage. To the author's knowledge, there has not been a fully grown NG in whom another life stage could be added to PTCO or the Nedunology model to advise future generations.

- c. A theoretical framework should be developed for the design and analysis of neuro-education and learning. A framework that can be used as a lens to view these three major elements will give direction in areas of importance to focus on in turn saving on time. Furthermore, to explore much deeper the student engagement dispositions where mental efforts are taken into consideration.

6.3 Final Remarks

This study has followed the argument that, if MTs are to change things and there is a desire to incorporate those aforementioned NG skills into the curriculum, then institutions and those who consider themselves as educators need to consider how technology changes thinking and in reality the physical size of the brain.

According to Robert Kuhn (2006), few people understand the complexity of that change; technology is creating new thinking that is at the same time creative and innovative, volatile and turbulent and nothing less than a shift in worldview. There is a continuous need to know the educational requirement, or gap, for which use of new media will potentially enhance learning.

REFERENCES AND APPENDICES

REFERENCES

- Aliyu, A. A., Bello, M. U., Kasim, R., & Martin, D. (2014). Positivist and Non-Positivist Paradigm in Social Science Research : Conflicting Paradigms or Perfect Partners ?, *4*(3), 79–95. doi:10.5539/jms.v4n3p79
- Andrews, L., Higgins, A., Andrews, M. W., & Lalor, J. G. (2012). Classic Grounded Theory to Analyse Secondary Data : Reality and Reflections, *11*(1), 12–26.
- Antonenko, P., Paas, F., Grabner, R., & Gog, T. van. (2010). Using electroencephalography to measure cognitive load. *Educational Psychology* Retrieved from <http://link.springer.com/article/10.1007/s10648-010-9130-y>
- Axelson, R., & Flick, A. (2011). Defining Student Engagement: The Magazine of Higher Learning, *43*: 1, 38-43. *Recuperado Em*. Retrieved from https://scholar.google.com/scholar?q=Axelson+and+Flick+2011&btnG=&hl=en&as_sdt=0%2C5#0
- Baccaglioni-Frank, A., & Maracci, M. (2015). Multi-Touch Technology and Preschoolers' Development of Number-Sense. *Digital Experiences in Mathematics Education*. doi:10.1007/s40751-015-0002-4
- Bankole, F. O., & Brown, I. (2011). Exploring the Impacts of ICT Investments on Dimensions of Human Development in Different Contexts : A Regression Splines Analysis.
- Baskerville, R., & Myers, M. (2009). Fashion waves in information systems research and practice. *Mis Quarterly*. Retrieved from <http://www.jstor.org/stable/20650319>
- Bavelier, D., Green, C. S., & Dye, M. W. G. (2010). Children, wired: for better and for worse. *Neuron*, *67*(5), 692–701. doi:10.1016/j.neuron.2010.08.035
- Bavelier, D., Green, C. S., Han, D. H., Renshaw, P. F., Merzenich, M. M., & Gentile, D. A. (2011). Brains on video games. *Nature Reviews Neuroscience*.
- Bavelier, D., Green, C. S., Pouget, A., & Schrater, P. (2012). Brain plasticity through the life span: learning to learn and action video games. *Annual Review of Neuroscience*, *35*, 391–416. doi:10.1146/annurev-neuro-060909-152832
- Bayne, S. (2014). What 's the matter with " technology- enhanced learning "? *Learning, Media and Technology*, (May), 37–41. doi:10.1080/17439884.2014.915851
- Beauchamp, M. S., Lee, K. E., Argall, B. D., & Martin, A. (2004). Integration of Auditory and Visual Information about Objects in Superior Temporal Sulcus. *Neuron*, *41*(5), 809–823. doi:10.1016/S0896-6273(04)00070-4
- Bell, M., Bell, W., Russell, D. L., Schneiderheinze, A., Carr, J., Tattersall, C., ... Dimitracopoulou, A. (2008). Development and evaluation of an interactive webquest environment: "Web Macerasi." *Educational Technology and Society*, *38*(3), 247–265. doi:10.1111/j.1467-8535.2008.00858.x

- Bennett, S., & Maton, K. (2010). Beyond the “digital natives” debate: Towards a more nuanced understanding of students’ technology experiences. *Journal of Computer Assisted Learning*. Retrieved from <http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2729.2010.00360.x/pdf>
- Bennett, S., Maton, K., & Kervin, L. (2008). The “digital natives” debate: A critical review of the evidence. *British Journal of Educational Technology*, 39(5), 775–786. doi:10.1111/j.1467-8535.2007.00793.x
- Berk, R. (2009). Multimedia teaching with video clips: TV, movies, YouTube, and mtvU in the college classroom. *International Journal of Technology in Teaching and ...* Retrieved from http://www.researchgate.net/profile/Ronald_Berk/publication/228349436_Multimedia_teaching_with_video_clips_TV_movies_YouTube_and_mtvU_in_the_college_classroom/links/00b7d529cc691422b0000000.pdf
- Bernard, H., & Ryan, G. (2009). Analyzing qualitative data: Systematic approaches. Retrieved from https://scholar.google.com/scholar?q=is+the+search+for+patterns+in+data+and+for+ideas+Bernard&btnG=&hl=en&as_sdt=0%2C5#2
- Bertelson, P., & De Gelder, B. (2004). The psychology of multimodal perception. *Crossmodal Space and Crossmodal Attention*, 141–177. doi:10.1093/acprof
- Bhattacharjee, A. (2012). *SOCIAL SCIENCE RESEARCH* : (2nd ed.). Tampa, Florida: Creative Commons Attribution.
- Booth, S. C., Weljie, A. M., & Turner, R. J. (2013). Computational tools for the secondary analysis of metabolomics experiments. *Computational and Structural Biotechnology Journal*, 4(5), e201301003. doi:10.5936/csbj.201301003
- BouDagher-Fadel, M. (2008). *Evolution and geological significance of larger benthic foraminifera*. Retrieved from https://books.google.com/books?hl=en&lr=&id=22SFkUA-7FUC&oi=fnd&pg=PP2&dq=Fadel+2008&ots=TemuqHOWO_&sig=HINmqEenNE9WRTZB0CorcNWoN4M
- Broman Toft, M., Schuitema, G., & Thøgersen, J. (2014). Responsible technology acceptance: Model development and application to consumer acceptance of Smart Grid technology. *Applied Energy*, 134, 392–400. doi:10.1016/j.apenergy.2014.08.048
- Burrell, G., & Morgan, G. (1979). *Sociological paradigms and organisational analysis*. Retrieved from http://opensource.telkomspeedy.com/repo/abba/v06/Kuliah/Seminar-MIS/2006/165/165-08-Social_Paradigm.pdf
- Busse, C. (2010). A procedure for secondary data analysis.pdf. *Journal of Supply Chain Management*, 46(4), 44–57.
- Caruso, J., & Salaway, G. (2007). The ECAR study of undergraduate students and information technology, 2008. Retrieved December. Retrieved from http://www.ccsu.edu/uploaded/websites/ITC/frontpagelinks/ECAR2008_RoadMap.pdf
- Carver, L. J., Meltzoff, A. N., & Dawson, G. (2006). Event-related potential (ERP) indices of infants’ recognition of familiar and unfamiliar objects in two and three dimensions. *Developmental Science*, 9(1), 51–62. doi:10.1111/j.1467-7687.2005.00463.x

- Cauda, F., D'Agata, F., Sacco, K., Duca, S., Geminiani, G., & Vercelli, A. (2011). Functional connectivity of the insula in the resting brain. *NeuroImage*, 55(1), 8–23. doi:10.1016/j.neuroimage.2010.11.049
- Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative research*. SagePublications Ltd, London. Retrieved from https://scholar.google.com/scholar?q=charmaz+2006+constructing+grounded+theory&btnG=&hl=en&as_sdt=0%2C5#4
- Cherlin, A. (1991). On analyzing other people's data. *Developmental Psychology*. Retrieved from <http://psycnet.apa.org/journals/dev/27/6/946/>
- Cherrett, T., Wills, G. B., Price, J., Maynard, S., & Dror, I. E. (2009, November 1). Making training more cognitively effective: making videos interactive. *British Journal of Educational Technology*. doi:10.1111/j.1467-8535.2009.00985.x <<http://dx.doi.org/10.1111/j.1467-8535.2009.00985.x>>).
- Cheung, A. C. K., & Slavin, R. E. (2012). How features of educational technology applications affect student reading outcomes: A meta-analysis. *Educational Research Review*, 7(3), 198–215. doi:<http://dx.doi.org/10.1016/j.edurev.2012.05.002>
- Clark, R. (1983). Reconsidering research on learning from media. *Review of Educational Research*. Retrieved from <http://rer.sagepub.com/content/53/4/445.short>
- Clark, R. C., Mayer, R. E., & Thalheimer, W. (2003). E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning. *Performance Improvement*, 42(5), 41–43. doi:10.1002/pfi.4930420510
- Collin, F. (2011). An Alternative Road for Science and Technology Studies and the Naturalization of Philosophy of Science. *Science Studies as Naturalized Philosophy*. Retrieved from http://link.springer.com/chapter/10.1007/978-90-481-9741-5_10
- Colzato, L. (2010). DOOM'd to switch: superior cognitive flexibility in players of first person shooter games. *Frontiers in ...*. Retrieved from <http://journal.frontiersin.org/Journal/10.3389/fpsyg.2010.00008/full>
- Coyer, S. M., & Gallo, A. M. (2005). Secondary analysis of data. *Journal of Pediatric Health Care : Official Publication of National Association of Pediatric Nurse Associates & Practitioners*, 19(1), 60–3. doi:10.1016/j.pedhc.2004.10.003
- Dahlstrom, E., Walker, J., & Dziuban, C. (2012). ECAR study of undergraduate students and information technology. Retrieved from <http://www.csus.edu/irt/cio/strategicplanning/Documents/Undergrad-Students-and-IT-2014-Full-Report.pdf>
- Dale, A. (2004). *Secondary Analysis of Quantitative Data : SAGE Research Methods*. Retrieved June 1, 2015, from <http://srmo.sagepub.com/view/the-sage-encyclopedia-of-social-science-research-methods/n896.xml>

- Davies, P. (2006). EXPLORATORY RESEARCH, *The SAGE Dictionary of Social Research Methods*, 111–112. Retrieved from <http://srmo.sagepub.com/view/the-sage-dictionary-of-social-research-methods/SAGE.xml>
- Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science*, 35(8), 982–1003. doi:10.1287/mnsc.35.8.982
- De Ribaupierre, A. (2015). *International Encyclopedia of the Social & Behavioral Sciences*. *International Encyclopedia of the Social & Behavioral Sciences*. Elsevier. doi:10.1016/B978-0-08-097086-8.23093-6
- Deubel, P. (2003). An investigation of behaviorist and cognitive approaches to instructional multimedia design. *Journal of Educational Multimedia and Hypermedia*. Retrieved from <http://www.editlib.org/p/17804/>
- Dewey, J. (1997). *The Collected Works of John Dewey, 1882-1953. The Electronic Edition*. Retrieved from <http://philpapers.org/rec/DEWTCW>
- Dictionary, O. (2014). Available at: http://scholar.google.com/scholar?q=Oxford+English+Dictionary+2014&btnG=&hl=en&as_sdt=0%2C5#0
- Ertmer, P. A., Ottenbreit-leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Computers & Education Teacher beliefs and technology integration practices : A critical relationship. *Computers & Education*, 59(2), 423–435. doi:10.1016/j.compedu.2012.02.001
- FAO. (2011). Quantitative Methods: Secondary Data. *Development Programmes on Food Security Quantitative Methods : Household Surveys Learners*.
- Farber, B., & Shafron, G. (2012). Children, technology, problems, and preferences. *Journal of Clinical* Retrieved from <http://onlinelibrary.wiley.com/doi/10.1002/jclp.21922/full>
- Fereday, J., & Muir-Cochrane, E. (2008, November 26). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*. Retrieved from <http://ejournals.library.ualberta.ca/index.php/IJQM/article/view/4411>
- Ferri, F., & Paolozzi, S. (2009). Analyzing multimodal interaction. *Multimodal Human Computer Interaction and* Retrieved from <https://books.google.com/books?hl=en&lr=&id=O8CqMtIKSWwC&oi=fnd&pg=PA19&dq=Ferri+and+Paolozzi+2009&ots=NZalSTGJTg&sig=adAUdLOx6xRkwTuVEIkmb23unul>
- Finn, J., & Zimmer, K. (2012). Student engagement: What is it? Why does it matter? *Handbook of Research on Student Engagement*. Retrieved from http://link.springer.com/chapter/10.1007/978-1-4614-2018-7_5
- Finn, J., Zimmer, K., & Christenson, S. (2012). *Handbook of research on student engagement*. Retrieved from https://scholar.google.com/scholar?q=Finn+and+Zimmer+2012&btnG=&hl=en&as_sdt=0%2C5#1

- Friedrichsen, P., Driel, J. H. Van, & Abell, S. K. (2011). Taking a closer look at science teaching orientations. *Science Education*, 95(2), 358–376. doi:10.1002/sce.20428
- Galliers, R. (1991). Choosing appropriate information systems research methodologies: a revised taxonomy. ... *and Emergent Traditions*. Amsterdam: North Holland. Retrieved from https://scholar.google.com/scholar?q=Galliers+1991+Taxonomy&btnG=&hl=en&as_sdt=0%2C5#0
- Glass, B. D., Maddox, W. T., & Love, B. C. (2013). Real-time strategy game training: emergence of a cognitive flexibility trait. *PLoS One*, 8(8), e70350. doi:10.1371/journal.pone.0070350
- Glass, G. V. (2014). *Primary, Secondary, and Meta-Analysis of Research* (Vol. 5). Colorado. Retrieved from <http://www.jstor.org/stable/1174772>.
- Gong, D., He, H., Liu, D., Ma, W., Dong, L., Luo, C., & Yao, D. (2015). Enhanced functional connectivity and increased gray matter volume of insula related to action video game playing. *Scientific Reports*, 5, 9763. doi:10.1038/srep09763
- Goswami, U. (2006). Neuroscience and education: from research to practice? *Nature Reviews Neuroscience*, 7(5), 406–413. doi:10.1038/nrn1907
- Green, C. S., & Bavelier, D. (2012). Learning, attentional control, and action video games. *Current Biology : CB*, 22(6), R197–206. doi:10.1016/j.cub.2012.02.012
- Groff, J., Howells, C., & Cranmer, S. (2010). The impact of console games in the classroom: Evidence from schools in Scotland. *Futurelab, UK*. Retrieved from https://scholar.google.com/scholar?q=Groff%2C+J.%2C+Howells%2C+C.%2C+%26+Cranmer%2C+S.%282010%29&btnG=&hl=en&as_sdt=0%2C5#0
- Hall, J. (n.d.). Neuroscience and Education A review of the contribution of brain science to teaching and learning.
- Heaton, J. (2008). Secondary Analysis of Qualitative Data : An Overview, 33(3), 33–45.
- Helsper, E. (2010). Gendered Internet use across generations and life stages. *Communication Research*. Retrieved from <http://crx.sagepub.com/content/early/2010/04/05/0093650209356439.abstract>
- Hinds, P. S., Vogel, R. J., & Clarke-Steffen, L. (1997). The Possibilities and Pitfalls of Doing a Secondary Analysis of a Qualitative Data Set. *Qualitative Health Research*, 7(3), 408–424. doi:10.1177/104973239700700306
- Howard-Jones, P. A. (2014). Neuroscience and education: myths and messages. *Nat Rev Neurosci, advance on*. Retrieved from <http://dx.doi.org/10.1038/nrn3817>
- Howard-jones, P., Ott, M., Leeuwen, T. Van, & De, B. (2014). The potential relevance of cognitive neuroscience for the development and use of technology-enhanced learning, (June), 37–41. doi:10.1080/17439884.2014.919321

- Hubert-Wallander, B., & Green, C. (2010). Altering the rate of visual search through experience: the case of action video game players. *Journal of ...*. Retrieved from <http://www.journalofvision.org/content/10/7/1300.short>
- Huitt, W., & Hummel, J. (2003). Piaget's theory of cognitive development. *Educational Psychology Interactive*. Retrieved from <http://studentlife.tamu.edu/sites/studentlife.tamu.edu/files/EDMWorkbook.pdf>
- Iucu, R. B., & Marin, E. (2014). Authentic Learning in Adult Education. *Procedia - Social and Behavioral Sciences*, 142, 410–415. doi:10.1016/j.sbspro.2014.07.702
- Jones, C., Ramanau, R., Cross, S., & Healing, G. (2010a). Computers & Education Net generation or Digital Natives : Is there a distinct new generation entering university ? *Computers & Education*, 54(3), 722–732. doi:10.1016/j.compedu.2009.09.022
- Jones, C., Ramanau, R., Cross, S., & Healing, G. (2010b). Net generation or Digital Natives: Is there a distinct new generation entering university? *Learning in Digital Worlds: Selected Contributions from the CAL 09 Conference*, 54(3), 722–732. doi:<http://dx.doi.org/10.1016/j.compedu.2009.09.022>
- Jonides, J., & Nee, D. (2006). Brain mechanisms of proactive interference in working memory. *Neuroscience*. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0306452205006238>
- Jung, R. E., & Haier, R. J. (2007). The Parieto-Frontal Integration Theory (P-FIT) of intelligence: converging neuroimaging evidence. *The Behavioral and Brain Sciences*, 30(2), 135–54; discussion 154–87. doi:10.1017/S0140525X07001185
- Kaboub, F. (2008). Positivist paradigm. *Encyclopaedia of Counselling*. Retrieved from <http://personal.denison.edu/~kabouf/Pub/2008-Positivist-Paradigm.pdf>
- Karle, J., Watter, S., & Shedden, J. (2010). Task switching in video game players: Benefits of selective attention but not resistance to proactive interference. *Acta Psychologica*. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0001691809001875>
- Kennedy, G., & Judd, T. (2010). Beyond natives and immigrants: exploring types of net generation students. *Journal of Computer ...*. Retrieved from <http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2729.2010.00371.x/full>
- Khwaja, H. A., Syed, H., & Cranston, D. W. (2002). Coding errors: a comparative analysis of hospital and prospectively collected departmental data. *BJU International*, 89(3), 178–180. doi:10.1046/j.1464-4096.2001.01428.x
- Klopfer, E., Osterweil, S., & Salen, K. (2009). Moving learning games forward. Retrieved from <https://hal.archives-ouvertes.fr/hal-00593085/>
- Koskinen, K. (2013). Epistemological Assumptions. *Knowledge Production in Organizations*. Retrieved from http://link.springer.com/chapter/10.1007/978-3-319-00104-3_7
- Kozma, R. (1994). A reply: Media and methods. *Educational Technology Research and Development*. Retrieved from <http://link.springer.com/article/10.1007/BF02298091>

- Krägeloh-Mann, I., & Wilke, M. (2009). *Finnie's Handling the Young Child with Cerebral Palsy at Home*. *Finnie's Handling the Young Child with Cerebral Palsy at Home*. Elsevier. doi:10.1016/B978-0-7506-8810-9.00004-6
- Krippendorff, K. (2011). Agreement and Information in the Reliability of Coding. *Communication Methods and Measures*, 5(2), 93–112. doi:10.1080/19312458.2011.568376
- Kühn, S., Lorenz, R., Banaschewski, T., Barker, G. J., Büchel, C., Conrod, P. J., ... Gallinat, J. (2014). Positive association of video game playing with left frontal cortical thickness in adolescents. *PLoS One*, 9(3), e91506. doi:10.1371/journal.pone.0091506
- Kvavik, R., Caruso, J., & Morgan, G. (2004). ECAR study of students and information technology, 2004: Convenience, connection, and control. Retrieved from <http://www.citeulike.org/group/2518/article/1278231>
- Lee, A. S. (1991). Integrating Positivist and Interpretive Approaches to Organizational Research. *Organization Science*. Retrieved from <http://pubsonline.informs.org/doi/abs/10.1287/orsc.2.4.342>
- Lee, J. (1994). Odds Ratio or Relative Risk for Cross-Sectional Data. *International Journal of Epidemiology* 23, (1), 201–203.
- Leong, V., & Goswami, U. (2014). Assessment of rhythmic entrainment at multiple timescales in dyslexia: evidence for disruption to syllable timing. *Hearing Research*, 308, 141–61. doi:10.1016/j.heares.2013.07.015
- Leppin, A. L., Bora, P. R., Tilburt, J. C., Gionfriddo, M. R., Zeballos-Palacios, C., Dulohery, M. M., ... Montori, V. M. (2014). The efficacy of resiliency training programs: a systematic review and meta-analysis of randomized trials. *PLoS One*, 9(10), e111420. doi:10.1371/journal.pone.0111420
- Leppink, J., Paas, F., Van der Vleuten, C. P. M., Van Gog, T., & Van Merriënboer, J. J. G. (2013). Development of an instrument for measuring different types of cognitive load. *Behavior Research Methods*, 45(4), 1058–72. doi:10.3758/s13428-013-0334-1
- Lohse, K., Shirzad, N., & Verster, A. (2013). Video games and rehabilitation: using design principles to enhance engagement in physical therapy. *Journal of Neurologic ...*. Retrieved from http://journals.lww.com/jnpt/Abstract/2013/12000/Video_Games_and_Rehabilitation__Using_Design.4.aspx
- Margaryan, A., Littlejohn, A., & Vojt, G. (2011). Are digital natives a myth or reality? University students' use of digital technologies. *Computers & Education*. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0360131510002563>
- Marno, H., & Csibra, G. (2015). Toddlers Favor Communicatively Presented Information over Statistical Reliability in Learning about Artifacts. *PLOS ONE*, 10(3), e0122129. doi:10.1371/journal.pone.0122129
- Mash, C., Bornstein, M. H., & Arterberry, M. E. (2013). Brain dynamics in young infants' recognition of faces: EEG oscillatory activity in response to mother and stranger. *Neuroreport*, 24(7), 359–63. doi:10.1097/WNR.0b013e32835f6828

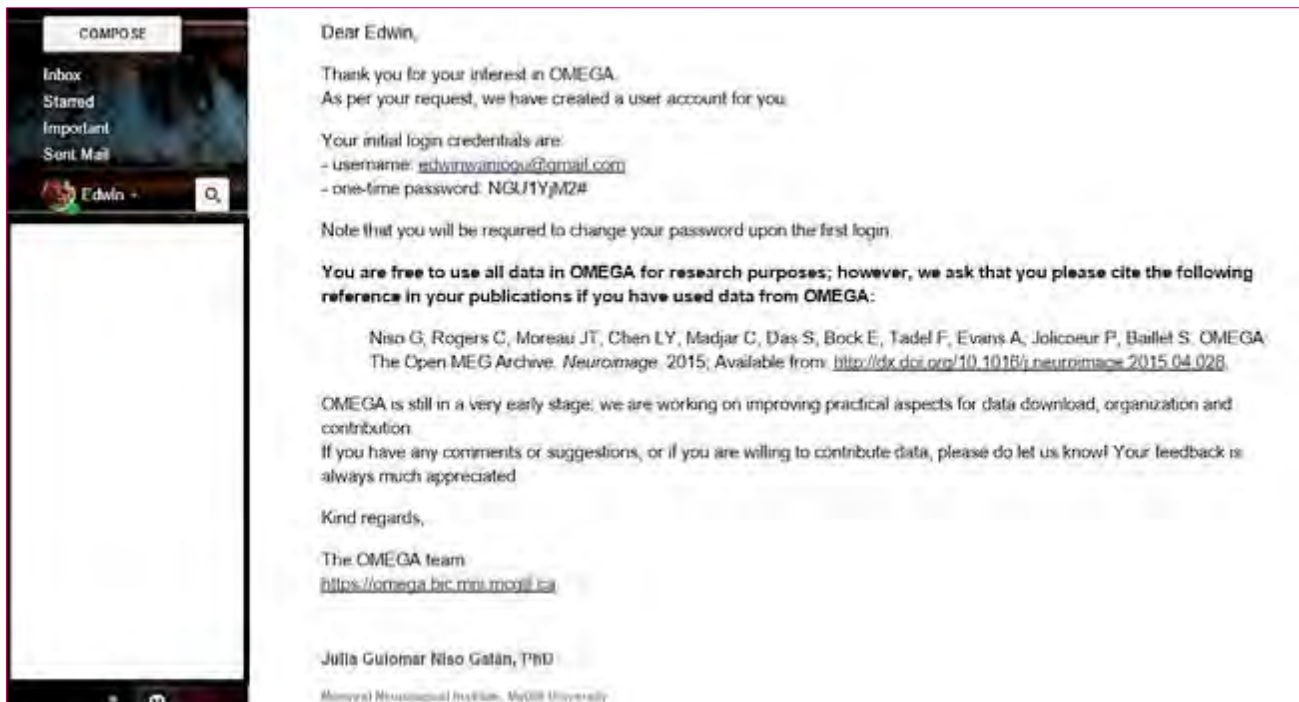
- Mayer, R. (2001). Cognitive Constraints on Multimedia Learning: When Presenting More Material Results in Less Understanding. *Journal of Educational Psychology, 93*(1).
- Mayer, R. (2009). *Multimedia learning*. Retrieved from http://books.google.co.za/books?hl=en&lr=&id=5g0AM1CHysgC&oi=fnd&pg=PR1&dq=cognitive+theory+of+multimedia+learning+by+richard+mayer&ots=T9-yHq62FT&sig=0qEwzyihOt_ISiRNYvc7A5PPZuE
- Mayer, R. E., & Moreno, R. (2003). Nine Ways to Reduce Cognitive Load in Multimedia Learning. *Educational Psychologist, 38*(1), 43–52. doi:10.1207/S15326985EP3801_6
- Mayer, R., & Moreno, R. (2002). Animation as an aid to multimedia learning. *Educational Psychology Review*. Retrieved from <http://link.springer.com/article/10.1023/A:1013184611077>
- McCoy, S., Galletta, D. F., & King, W. R. (2007). Applying TAM across cultures: the need for caution. *European Journal of Information Systems, 16*(1), 81–90. doi:10.1057/palgrave.ejis.3000659
- Merlino, N., & Rhodes, R. (2012). Technology in the 21 st Century Classroom: Key Pedagogical Strategies for Millennial Students in University Business Courses. *Journal of Supply Chain and Operations* Retrieved from http://csupom.org/PUBLICATIONS/2012-1/JSCOM_2012-1-9.pdf
- Moreno, R., & Mayer, R. (2007). Interactive Multimodal Learning Environments. *Educational Psychology Review, 19*(3), 309–326. Retrieved from <http://www.editlib.org/p/72985/>
- Moser, A., Zimmermann, L., Dickerson, K., Grenell, A., Barr, R., & Gerhardstein, P. (2015). They can interact, but can they learn? Toddlers' transfer learning from touchscreens and television. *Journal of Experimental Child Psychology, 137*, 137–155. doi:10.1016/j.jecp.2015.04.002
- Müller, S. (2013). Unifying everything: Some remarks on simpler syntax, construction grammar, minimalism, and HPSG. *Language*. Retrieved from <http://muse.jhu.edu/journals/language/v089/89.4.muller.html>
- Mustard, J. (2010). Early brain development and human development. *Encyclopedia on Early Childhood Development*. Retrieved from <http://www.child-encyclopedia.com/Pages/PDF/MustardANGxp.pdf>
- Nouchi, R., Taki, Y., Takeuchi, H., Hashizume, H., Nozawa, T., Kambara, T., ... Kawashima, R. (2013). Brain Training Game Boosts Executive Functions, Working Memory and Processing Speed in the Young Adults: A Randomized Controlled Trial. doi:doi:10.6084/m9.figshare.155945
- Novak, E., & Tassell, J. L. (2015). A dataset for education-related majors' performance measures with pre/post-video game practice. *British Journal of Educational Technology, n/a–n/a*. doi:10.1111/bjet.12287
- Oblinger, D., Oblinger, J. L., & Lippincott, J. K. (2005). *Educating the Net Generation*.
- Ocepek, U., Bosnić, Z., Nančovska Šerbec, I., & Rugelj, J. (2013). Exploring the relation between learning style models and preferred multimedia types. *Computers & Education, 69*(0), 343–355. doi:<http://dx.doi.org/10.1016/j.compedu.2013.07.029>

- Oliver, B., & Goerke, V. (2007). Australian undergraduates' use and ownership of emerging technologies: Implications and opportunities for creating engaging learning experiences for the Net. *Australasian Journal of Educational Technology*. Retrieved from <http://ascilite.org.au/ajet/submission/index.php/AJET/article/view/1263>
- Paivio, A., & Csapo, K. (1973). Picture superiority in free recall: Imagery or dual coding? *Cognitive Psychology*. Retrieved from <http://www.sciencedirect.com/science/article/pii/0010028573900327>
- Piaget, J. (1976). *Piaget's theory*. Retrieved from http://link.springer.com/chapter/10.1007/978-3-642-46323-5_2
- Prensky, M. (2005). Listen to the Natives. *Educational Leadership*, 63(4), 8–13. Retrieved from <http://eric.ed.gov/?id=EJ745468>
- Reiser, R. A. (2001). A history of instructional design and technology: Part I: A history of instructional media. *Educational Technology Research and Development*, 49(1), 53–64. doi:10.1007/BF02504506
- Rew, L., Koniak-Griffin, D., Lewis, M. A., Miles, M., & O'Sullivan, A. (2000). Secondary data analysis: New perspective for adolescent research. *Nursing Outlook*, 48(5), 223–229. doi:10.1067/mno.2000.104901
- Roodt, S., & Peier, D. (2013). Using Youtube © in the Classroom for the Net Generation of Students, 10.
- Rosenthal-von der Pütten, A. M., Schulte, F. P., Eimler, S. C., Sobieraj, S., Hoffmann, L., Maderwald, S., ... Krämer, N. C. (2014). Investigations on empathy towards humans and robots using fMRI. *Computers in Human Behavior*, 33, 201–212. doi:10.1016/j.chb.2014.01.004
- Rowan, C. (2010). Unplug—Don't Drug: A Critical Look at the Influence of Technology on Child Behavior With an Alternative Way of Responding Other Than Evaluation and Drugging. *Ethical Human Psychology and Psychiatry*. Retrieved from <http://www.ingentaconnect.com/content/springer/ehpp/2010/00000012/00000001/art00006>
- S, K., Y, A.-D., Rj, H., Ij, D., Oc, L., C, L., & Ac, E. (2009). Positive association between cognitive ability and cortical thickness in a representative US sample of healthy 6 to 18 year-olds. *Intelligence*, 37(2), 145–155. doi:10.1016/j.intell.2008.09.006
- Saunders, M., Lewis, P., & Thornhill, A. (2009). *for business students fi fth edition* (5th ed.). Italy: Pitman Publishing imprint.
- Schmader, T., & Johns, M. (2003). Converging evidence that stereotype threat reduces working memory capacity. *Journal of Personality and Social Psychology*, 85(3), 440–52. doi:10.1037/0022-3514.85.3.440
- Schmidt, B., & Stewart, S. (2009). Implementing the Virtual Reality Learning Environment: Second Life. *Nurse Educator*, 34(4). Retrieved from http://journals.lww.com/nurseeducatoronline/Fulltext/2009/07000/Implementing_the_Virtual_Reality_Learning.7.aspx

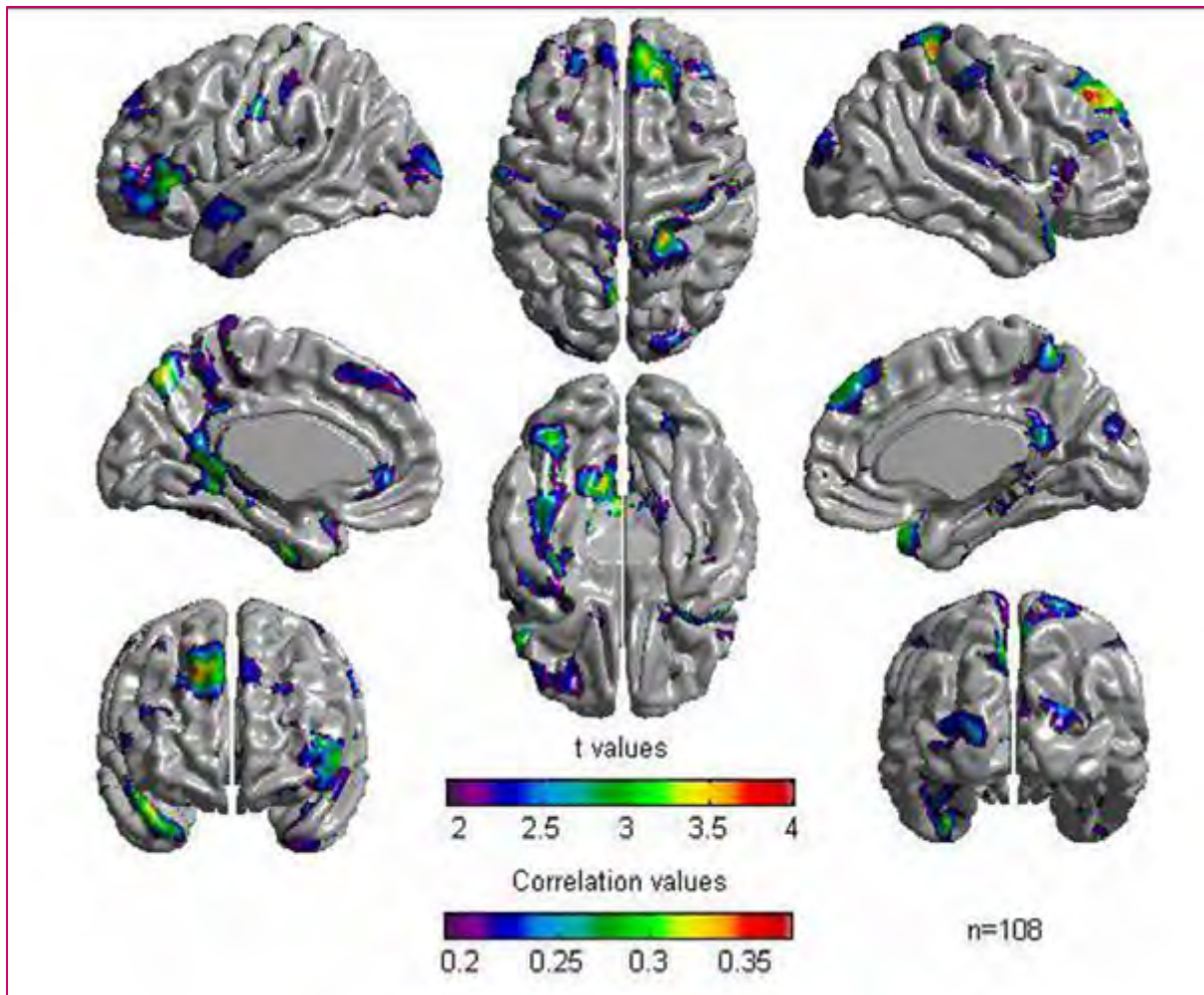
- Schweppe, J., Eitel, A., & Rummer, R. (2015). The multimedia effect and its stability over time. *Learning and Instruction, 38*, 24–33. doi:10.1016/j.learninstruc.2015.03.001
- Sekaran, U. (2003). *Research methods for business*. Hoboken. Retrieved from https://scholar.google.com/scholar?q=Sekaran+2003&btnG=&hl=en&as_sdt=0%2C5#2
- Sherry, J. L. (2013). Formative Research for STEM Educational Games. *Zeitschrift Für Psychologie, 221*(2), 90–97. doi:10.1027/2151-2604/a000134
- Sigman, M., Peña, M., Goldin, A. P., & Ribeiro, S. (2014). review Neuroscience and education : prime time to build the bridge, *17*(4), 497–502. doi:10.1038/nn.3672
- Srisawasdi, N., & Panjaburee, P. (2014). Technology-enhanced Learning in Science, Technology, and Mathematics Education: Results on Supporting Student Learning. *Procedia - Social and Behavioral Sciences, 116*, 946–950. doi:10.1016/j.sbspro.2014.01.325
- Stewart, P. C. (2015). This Is Your Brain on Psychology: Wireless Electroencephalography Technology in a University Classroom. *Teaching of Psychology, 0098628315587621*–. doi:10.1177/0098628315587621
- Szucs, D., Devine, A., Soltesz, F., Nobes, A., & Gabriel, F. (2013). Developmental dyscalculia is related to visuo-spatial memory and inhibition impairment. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior, 49*(10), 2674–88. doi:10.1016/j.cortex.2013.06.007
- Tahir, M. A., Yan, F., Koniusz, P., Awais, M., Barnard, M., Mikolajczyk, K., ... Kittler, J. (2013). A Robust and Scalable Visual Category and Action Recognition System Using Kernel Discriminant Analysis With Spectral Regression. *IEEE Transactions on Multimedia, 15*(7), 1653–1664. doi:10.1109/TMM.2013.2264927
- Tapscott, D. (1999). Educating the net generation. *Educational Leadership*. Retrieved from <http://eric.ed.gov/?id=EJ581511>
- Tapscott, D. (2009). *Grown up digital*. Retrieved from <http://media.economist.com/media/pdf/grown-up-digital-tapscott-e.pdf>
- Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education, 2*, 53–55. doi:10.5116/ijme.4dfb.8dfd
- Teo, T. (2009). Modelling technology acceptance in education: A study of pre-service teachers. *Computers & Education, 52*(2), 302–312. doi:10.1016/j.compedu.2008.08.006
- Trepule, E., Tereseviciene, M., & Rutkiene, A. (2015). Didactic Approach of Introducing Technology Enhanced Learning (TEL) Curriculum in Higher Education. *Procedia - Social and Behavioral Sciences, 191*, 848–852. doi:10.1016/j.sbspro.2015.04.340
- Upadhyay, S. (2011). Piaget's Theory of Cognitive Development. Retrieved from <http://www.ssmrae.com/admin/images/5d1fbcacac19057ab0e17779cfef0e96.pdf>
- V. Rideout, E. H. (2006). *The Media Family: Electronic Media in the Lives of Infants, Toddlers, Preschoolers and Their Parents*.

- Vygotsky, L. (1980). *Mind in society: The development of higher psychological processes*. Retrieved from <https://books.google.com/books?hl=en&lr=&id=Irq913IEZ1QC&oi=fnd&pg=PR13&dq=Vygotsky+%26+Vygotsky,+1980&ots=H9EIB1Bkki&sig=j-Jk2QDOkk1JMJuZYGiyPrxqmTE>
- Waismeyer, A., Meltzoff, A. N., & Gopnik, A. (2015). Causal learning from probabilistic events in 24-month-olds: an action measure. *Developmental Science*, *18*(1), 175–82. doi:10.1111/desc.12208
- Walker, R., Voce, J., Nicholls, J., Swift, E., Ahmed, J., Horrigan, S., & Vincent, P. (2014). *UCISA*. London.
- Ward, V. (2013). Toddlers becoming so addicted to iPads they require therapy. *The Telegraph*. Retrieved from http://savepccs.com/pdf/toddlers_addicted_ipads_require_therapy.pdf
- Wilson, M., & Gerber, L. (2008). How generational theory can improve teaching: Strategies for working with the “Millennials.” *Currents in Teaching and Learning*. Retrieved from http://www.worcester.edu/Currents/Archives/Volume_1_Number_1/CurrentsV1N1WilsonP29.pdf
- Windle, P. E. (2010). Secondary data analysis: is it useful and valid? *Journal of Perianesthesia Nursing : Official Journal of the American Society of PeriAnesthesia Nurses / American Society of PeriAnesthesia Nurses*, *25*(5), 322–4. doi:10.1016/j.jopan.2010.07.005
- Winkler, A. M., Kochunov, P., Blangero, J., Almasy, L., Zilles, K., Fox, P. T., ... Glahn, D. C. (2010). Cortical thickness or grey matter volume? The importance of selecting the phenotype for imaging genetics studies. *NeuroImage*, *53*(3), 1135–46. doi:10.1016/j.neuroimage.2009.12.028
- Wood, E., Zivcakova, L., & Gentile, P. (2012). Examining the impact of off-task multi-tasking with technology on real-time classroom learning. *Computers & ...*. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0360131511002077>
- Yu, Z., Yu, W. H., Fan, X., & Wang, X. (2014). An exploration of computer game-based instruction in the “world history” class in secondary education: a comparative study in China. *PloS One*, *9*(5), e96865. doi:10.1371/journal.pone.0096865
- Zack, E., Barr, R., Gerhardstein, P., Dickerson, K., & Meltzoff, A. N. (2009). Infant imitation from television using novel touch screen technology. *British Journal of Developmental Psychology*, *27*(1), 13–26. doi:10.1348/026151008X334700
- Zack, E., Gerhardstein, P., Meltzoff, A. N., & Barr, R. (2013). 15-month-olds’ transfer of learning between touch screen and real-world displays: language cues and cognitive loads. *Scandinavian Journal of Psychology*, *54*(1), 20–5. doi:10.1111/sjop.12001

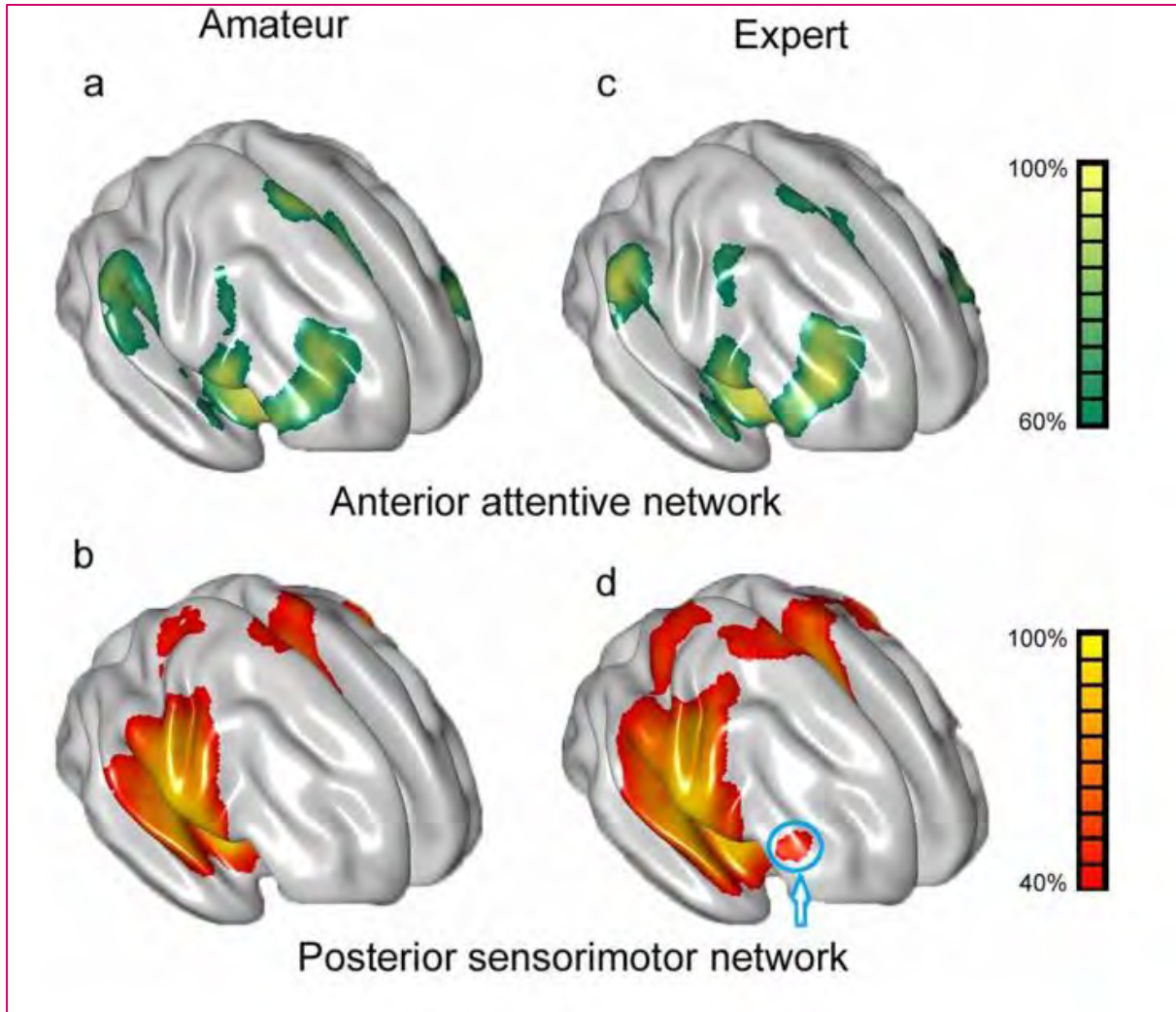
Appendix A: Email Authentication for Database Access



Appendix B: Brain Scans Used in Analysis Two



Appendix C: Brain Scans Used in Analysis Three, Data Set Two



Appendix D: Ethics Approval Form

Commerce Faculty Ethics in Research Committee Updated Ethics Form March 2013

Any individual in the Faculty of Commerce at the University of Cape Town undertaking any research that involves the use of human subjects, or research that may hold ethical consequences for the University of Cape Town, is required to complete this form and obtain approval before conducting research. The completed form should be submitted as an electronic document to departmental Ethics Committee representatives for submission to the Commerce Faculty Ethics in Research Committee. Please also submit electronic copies of your research proposal, informed consent form or other information used to obtain consent, and any questionnaires other material shown to subjects.

1. PROJECT DETAILS		
Project title:	Potential relevance of neuroscience to guide consumption of multimedia technologies towards enhancing learning.	
Principal Researcher/s:	EDWIN WANJOGU	Email address(es): WNJEDW001@myuct.ac.za
Research Supervisor:	DR. SUMARIE ROODT	Email address(es): Sumarie.roodt@myuct.ac.za
Co-researcher(s):		Email address(es):
Brief description of the project: This study is aimed at determining at what age, what kind of technology/multimedia is appropriate for the student that will enhance their learning whilst at the same time heightening their cognitive development.		
Data collection: (please select) <input type="checkbox"/> Interviews <input type="checkbox"/> Questionnaire <input type="checkbox"/> Experiment <input checked="" type="checkbox"/> Secondary data <input type="checkbox"/> Observation <input type="checkbox"/> Other (please specify): _____		

Procedure: (please describe)

Secondary analysis of data. Using data found from the database search collected in a primary study (Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009; Novak & Tassell, 2015; Gong et al., 2015) is used to answer new research questions that are in this study. Electronic searches were performed via the following databases: WorldCat, eLIFE, PLoS, OMEGA ScienceDirect, PubMed, Scopus, Digital Dissertations on ProQuest, EBSCO CINAHL, Ovid MEDLINE, Ovid EMBASE, Ovid Cochrane Library, Web of Science, WHO and Ovid PsycINFO.

2. PARTICIPANTS

Characteristics of participants: **NA**

Gender:

Race / Ethnicity:

Age range:

Location:

Other:

Race / Ethnicity:

Have you included a "Prefer not to Answer" response category in your questionnaire? (please select)

Yes No Not applicable

If you answered 'No' why not?

Affiliations of participants: (please select)

Company employees UCT staff General public UCT Students

Other (please specify): SAMPLES IDENTIFIED IN THE PRIMARY STUDIES BELOW:

(Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009)

(Novak & Tassell, 2015)

(Gong et al., 2015)

If your sample includes children (aged 18 and below), mentally incompetent persons, or legally restricted groups please explain below why it is necessary to use these particular groups. If subjects are minors or mentally incompetent, please describe how and by whom permission will be granted? If you are including children under the age of 18 and are not getting parental consent, please explain why you believe that their parents would consent if it was possible to contact them.

3. ORGANISATIONAL PERMISSION

If your research is being conducted within a specific organisation, please provide organisational permission or explain how permission will be obtained.

Are you making use of UCT students as respondents for your research? (please select) Yes No
If yes, have you contacted Executive Director: Student Affairs for permission? (please select) Yes No
Was approval granted? (please select) Yes No Awaiting a response

Are you making use of UCT staff as respondents for your research? (please select) Yes No
If yes, have you contacted Executive Director: Human Resources for permission? (please select) Yes No
Was approval granted? (please select) Yes No Awaiting a response

Contact Emails: Executive Director: Human Resources (Miriam.Hoosain@uct.ac.za)
Executive Director: Student Affairs (Moonira.Khan@uct.ac.za)

4. INFORMED CONSENT

What type of consent will be obtained from study participants?

written consent

anonymous survey

oral consent (please justify)

other (please specify)

Oral Consent

Written Consent

Anonymous survey questionnaire (covering letter required, no consent form needed)

Other (please specify)

How and where will consent/permission be recorded?

5. CONFIDENTIALITY OF DATA

What precautions will be taken to safeguard identifiable records of individuals? Please describe specific procedures to be used to provide confidentiality of data by you and others, in both the short and long run. This question also applies if you are using secondary sources of data that is not anonymous.

1. Anonymizing of the data and ensuring no bio-data is used in the final statistical analysis without devaluing the data.
2. Ensuring there was documented original consent in the data sets for the above mentioned studies.
3. Actions in accordance with the laws on copyright and data protection were adhered to.

6. RISK TO PARTICIPANTS

Does the proposed research pose any physical, psychological, social, legal, economic, or other risks to study participants you can foresee, both immediate and long range? (please select)

Yes No

If yes, answer the following questions:

1. Describe in detail the nature and extent of the risk and provide the rationale for the necessity of such risks
2. **Outline any alternative approaches that were or will be considered and why alternatives may not be feasible in the study**

1.

2.

3.

What authorship agreement have you reached with your co-researchers or supervisor?

This research is not intended for publication

Standard authorship agreement (principal researcher first author, co-researcher(s) and supervisor(s) co-authors)

Customised agreement (please specify below):

I certify that we have read the the UCT Authorship Policy, and Commerce Faculty Authorship Guidelines

(<http://www.commerce.uct.ac.za/Commerce/Information/research.asp>)

I certify that that the material contained herein is truthful and that all co-researchers and supervisors are

aware of the contents thereof.

I understand that it is my responsibility to conduct research in accordance with the ethical requirements of

UCT.

Signed by candidate

Signature Removed

Applicant's signature:

Date:

CHECKLIST

A full copy of a research proposal or a literature review with methodology is attached

SELECT



Research proposal/ interview schedules / cover letters / questionnaires / forms and other materials used in the study are attached/ consent form



Organisational consent letter / UCT student or staff approval letter

NA



On your cover letter to your questionnaire have you included the following?

1. The following UCT Logo



NA

2. A sentence explaining the aim of the research

3. Sentences of a similar nature to below must be included in the cover letter or consent form:

This research has been approved by the Commerce Faculty Ethics in Research Committee.

Your participation in this research is voluntary. You can choose to withdraw from the research at any time.

The questionnaire will take approximately X minutes to complete

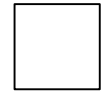
You will not be requested to supply any identifiable information, ensuring anonymity of your responses.

Due to the nature of the study you will need to provide the researchers with some form of identifiable information however, all responses will be confidential and used for the purposes of this research only.

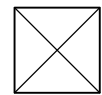
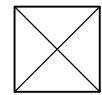
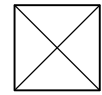
Should you have any questions regarding the research please feel free to contact the researcher (insert contact details).

4. Have you scanned in your signature for the last section of the form?

NA



OR



For Ethics committee representative only

Recommendation(s):

Signature:

Date:

For Ethics committee chairperson only

Recommendation:

Signature:

Date: