The effectiveness of brain-compatible blended learning material in the teaching of programming logic

by

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Abstract

Blended learning is an educational approach which integrates seemingly distinct educational approaches such as face-to-face and online experiences. In a blended learning environment the classroom lectures can, for example, be augmented with learning material offered in a variety of technologically delivered formats. Brain-compatible learning is an approach to education which stems from a combination of neuroscience and educational psychology. Brain-compatible learning is not a formalised education approach or 'recipe for teachers', instead it provides a 'set of principles and a base of knowledge and skills upon which we can make better decisions about the learning process'. While the effectiveness of education based on brain-compatible learning principles have been proven in a classroom environment, very little knowledge exist regarding its use in an e-learning environment. The purpose of this research was to determine whether or not an e-learning intervention which was designed according to brain-compatible learning principles would have an effect on student motivation to learn and on student achievement in the subject *Technical Programming 1*. An e-learning based educational intervention which incorporated several brain-compatible learning principles was designed and administered as a controlled experiment intervention. The impact of the research experiment was measured both qualitatively using an purpose-designed instrument and quantitatively through an analysis of the formal assessments for this subject. The findings of this study, namely that brain-compatible learning principles can be used in an e-learning environment and that e-learning material which adheres to brain-compatible education principles have a positive effect on *Technical Programming 1* students' achievement and motivation to learn, appear to be meaningful contributions to the current debate on blended learning.

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INTRODUCTION

1.1 Introduction

We live in a world where what one can, or cannot, do is often governed by the availability of limited resources. As such, there is increasing pressure on all aspects of modern society to use resources more effectively. This is accompanied by increasingly fiercer competition for access to these limited resources. To a large extent, it is the responsibility of governments to allocate such resources in a way that most appropriately addresses the needs of society. One of the key areas to which governments can allocate resources is education. Education plays an important role in society in general and is also one of the few widely acknowledged ways to truly combat poverty. As such, access to education is of paramount importance. In South Africa the higher educational landscape is continually evolving to try to accommodate an increasingly larger need for tertiary education. The need for access to tertiary education has grown to the extent where individuals have literally been trampled to death at the gates of tertiary educational institutions (SAPA, 2012).

It is thus of paramount importance that those who do gain access to this scare resource also are afforded the maximum opportunity possible to attain the desired education. Universities have to continuously balance the need for maintaining high educational standards with the need to both optimize the throughput of students in the educational system and maximize the number of students serviced by the educational institution. This is especially true in the South African context where there is increasing pressure on higher educational institutions to facilitate greater access and to increase throughput rates (Boughey, 2003).

Unfortunately, this goal is not necessarily accompanied by an increase in available resources allocated to achieving the goal. Often university lecturers are expected to maintain the high standards and pass rates of previous years despite having to lecture to substantially larger classes using the same amount of allocated resources. Increased class sizes at universities usually also means that lecturers have less time available for personal attention to students (Blatchford, Bassett, & Brown, 2011). Such large university classes can lead to a situation where it is nearly impossible to personalize the learning experience by providing one-to-one teaching and/or hands-on experience (Bersin, 2004). However, most university students are adults who already have well established learning styles and preferences and who also often have to manage multiple responsibilities and demands on their time (Clapper, 2010; Materna, 2007). The educational approach followed in the classroom may not necessarily match these learning styles and preferences, or allow for the multiple demands on a students time.

One way to augment traditional classroom education and to provide support for both a greater variety of learning styles, as well as more flexibility in terms of time spend learning is the use of blended and/or e-learning material (Bersin, 2004). Blended learning is an educational approach which integrates seemingly distinct educational approaches, such as face-to-face and online experiences (Means, Toyama, Murphy, Bakia, & Jones, 2009). In a blended learning environment the classroom lectures can, for example, be augmented with learning material offered in a variety of technologically delivered formats. Researchers have found extensive evidence that a blended learning approach which mixes face-to-face and online learning materials is substantially more effective than using only face-to-face educational methods (Means et al., 2009). However, in order to be effective blended learning course material should still be designed and presented according to sound pedagogical principles (Heinze, 2008; Torrao & Tiirmaa-Oras, 2007).

In the field of Information Technology, programming is considered a core skill as programming concepts are used in almost all core courses (Lunt et al., 2008). At its most basic, this skill can further be subdivided into two core modules, namely “Fundamental Programming Constructs” and “Algorithms and Problem Solving" (Lunt et al., 2008, pp. 32). Both of these core modules thus form part of the curriculum for the National Diploma: Software Development as offered by the Information Technology Department at the Nelson Mandela Metropolitan University (NMMU, 2012).

Students studying towards the National Diploma: Software Development qualification get their first exposure to the above mentioned core areas in the subject 'Development Software 1'. This initial exposure is then reinforced in their second year by the subject 'Technical Programming 1', which specifically focusses on the reinforcement of the problem solving strategies and algorithm design skills introduced in their first year. The skills learned in this subject are considered essential for the analyses and design of information technology business solutions(Lunt et al., 2008). It is thus vital for these students to master these skills.

However, this subject has a very high drop-out and failure rate. During 2011, for example, only 44.4% of students who initially enrolled in this subject successfully completed the subject . Apart from the obvious negative impact such a high failure rate has on student retention and throughput, it should also be noted that even students passing the course often have very low marks. Since this subject teaches one of the fundamental skills needed in this field of study, increased understanding of the concepts taught would be also be beneficial to the overall success of students in this qualification. The high failure rate associated with the Technical Programming 1 subject can possibly be attributed to several factors. These factors include, but are not necessarily limited to:

- The large size of the class:
  - At the start of 2011 the theory classes consisted of a single group of 192 students.
  - Practical classes during 2011 contained an average of 40 students per practical class group.
- The complexity and technical nature of the subject matter.
- The possible lack of related and foundational logical problem solving skills of the students entering the course.

- Language problems: Many of the students are not English first language speakers.
- A lack of high quality peer support.

As mentioned earlier, it might be possible to address, or partially address, several of the above mentioned problems through the introduction of e-learning based material into the curriculum for this subject. Such material will not serve to replace the lecturers function but rather to augment the actual lectures. This material would, however, have to be based on a pedagogically sound educational approach. One such an approach is brain compatible learning.

Brain-compatible learning is an approach to education which is based on the underlying "biology of learning" instead of "simply following traditional practices" (McGeehan, 2001, p. 9). This educational approach stems from a combination of neuroscience and educational psychology and was first made possible by advances in brain imaging during the 1990s (McGeehan, 2001). The term "brain-compatible learning" was first coined by Leslie Hart in 1983 in his book Human Brain and Human Learning to refer to "education designed to match "settings and instruction to the nature of the brain, rather than trying to force [the brain] to comply with arrangements established with virtually no concern for what this organ is or how it works best"" (McGeehan, 2001, pp. 7-8).

Brain research have shown that humans literally grow new dendrites and neural connections every time we learn something (Lombardi, 2008). Knowing which educational activities are the most effective in stimulating such growth allows educationalists to create material leveraging the way the brain naturally learns. Through such knowledge the "educational process could be significantly enhanced for most students" (Taylor, 2008, p. 43).

Since its inception, brain-compatible learning techniques have been used extensively in classroom environments and the effectiveness of brain-compatible approaches have, despite some criticisms, been proven (Winters, 2001). Many practical guidelines given for the adoption of brain-compatible principles are specific to classroom environments (Taylor, 2008; Smilkstein, 2003), however some studies also focus on the incorporation of such principles in the design of computer based education materials (Bradshaw, 2003). It could be argued that most of the brain-compatible learning principles identified by previous researchers can also be used in the implementation of e-learning based learning materials. However, little or no research exists relating specifically to the use of brain-compatible principles to design e-learning based material to assist students in learning algorithm and problem solving skills. This research project aims to investigate the suitability of e-learning material which has been developed based on brain-compatible learning principles to address the learning needs of information technology students in the subject Technical Programming 1.

1.2 Problem Statement

The subject Technical Programming 1 (PRT1000) in the Department of Information Technology at the Nelson Mandela Metropolitan University has a very high failure and drop-out rate. The subject material taught in this course forms a core component of the education of software development students. Mastery of this material is vital for their continued success in the National Diploma: Software Development qualification.

1.3 Thesis Statement

The use of brain compatible educational techniques in blended/ e-learning material can improve the learning of logical problem solving skills amongst information technology students.

1.4 Research Questions

The primary research question to be answered by this research is: *Can e-learning material based on brain-compatible learning principles improve the learning of students in the subject Technical Programming 1?* In order to answer the above primary question, the following secondary research questions have been identified:

- *Which brain-compatible learning principles could be used in the explanation of subject material dealing with algorithms and problem solving?*

- *How can the identified brain-compatible learning principles be applied in an e-learning environment?*
- *What effect will the use of brain-compatible e-learning material have on the motivation of students to learn?*
- *What effect will the use of brain-compatible e-learning material have on the student achievement?*

1.5 Research Objectives

The primary research objective of this study is *to investigate the use of brain-compatible e-learning material for the teaching of algorithms and problem solving skills.*

Secondary research objectives for this study include:

- *To determine how brain-compatible principles can be used in an e-learning environment.*
- *To investigate whether the use of brain-compatible e-learning material improve student motivation to use such additional materials.*
- *To investigate whether the use of brain-compatible e-learning material improve student achievement.*

1.6 Research Design and Methodology

All research begins with philosophical assumptions (Collins & Hussey, 2003). Even if the researcher him/her-self is unaware of these assumptions, they still exist. Every person has a certain world view or ontology and to a certain extent this world view will influence his/her research. The choice of a research paradigm and methodology will also be influenced by this world view. Figure 1 show the core ontological assumptions which might stem from a researcher's beliefs.

A researcher whose primary paradigmatic stance leans towards the quantitative side of the continuum, view reality as a concrete structure and believes that it is possible to objectively measure this reality. This extreme

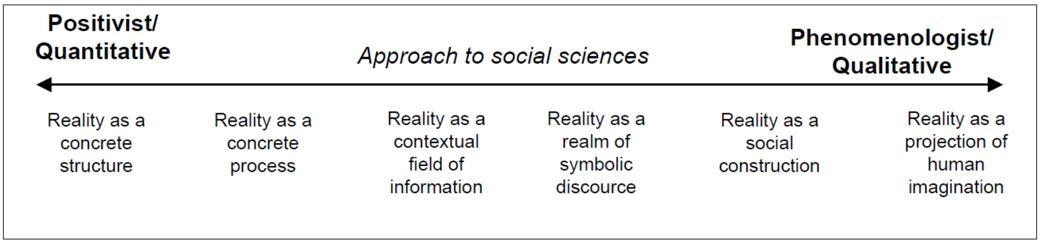

Figure 1.1: Continuum of core ontological assumptions from Collins & Hussey (2003)

of the philosophical continuum has been widely used and accepted in the natural sciences. At the other extreme, researchers leaning towards the qualitative side interpret reality as a projection of human imagination. In such a qualitative world view the subjective nature of the human doing the research is acknowledged and this form of research tends to focus more on the interpretation of the research than on the measurement of results (Collins & Hussey, 2003, p. 53) This research will take a pragmatic approach which use both qualitative and quantitative techniques. Qualitative data will be generated via interviews, questionnaires, and learner observation. Quantitative data will be collected in the form of actual results stemming from formal assessments (semester test and/or examination results) as well as through a research experiment. The qualitative data will be analysed interpretively in order to determine how learners experienced the developed brain-compatible e-learning material. Data analyses and argumentation techniques as described by (Mason, 1996), will be used to interpret the results. The quality of the results will be ensured using various techniques, as described by Meyrick (2006), Collingridge (2008). Quantitative data will be gathered by means of a research experiment. The exact parameters of this experiment will be determined with the aid of the unit for statistical services. However, at this stage it was envisaged that a sample group of at least 40 students would be given access to the developed material. The performance of these students was compared to the rest of the class, which acted as a control group. The null hypotheses for this experiment was that the sample group will not perform significantly better in post-experiment tests than the control group.

1.7 Ethical Considerations

The Technical Programming 1 subject is currently not being taught by me. I have taught the subject in the past and am thus very familiar with the specific needs of students in this subject. However, no current power relationship exists between myself and the specific students enrolled for the subject. *This research project received approval from the NMMU research ethics committee (Ref H12-EDU-ERE-031).*

1.8 Layout of the dissertation

The remainder of the dissertation is laid out as follows:

Chapter 2: Literature Review

This chapter provides the theoretical basis for the research. It introduces the field of brain-compatible learning, provides the reasons for using a blended-learning approach, and briefly introduces the relevant components of programming education this research focusses on.

Chapter 3: Methodology and Research Design

This chapter presents the researchers paradigmatic stance, the research process and methodology followed in the research, and the design of the research intervention and data gathering instruments.

Chapter 4: Results

This chapter presents the analyses of both the quantitative and qualitative results of this study.

Chapter 5: Conclusion and Discussion

This chapter concludes the research. It interprets the results from chapter 4, discusses how the research questions posed in chapter 1 was answered, highlights implications of the research, and finally presents opportunities for future studies.

Appendices

Research instruments and documents used during this study are presented in the appendices to the dissertation.

Chapter 2

Literature Review

2.1 Introduction

The purpose of this chapter is to provide a clear and concise overview of the literature relevant to this research and to establish a theoretical framework for the remainder of the study. The study integrates concepts from two sub-fields, namely; *brain compatible learning* and *blended learning.* In addition to these two sub-fields, the chapter will also provide a brief overview of the fundamental programming concepts which were used in the research intervention.

The chapter also provides a brief overview of learning theories and principles in general before providing a more specific review of brain compatible learning. The aim of the review of brain-compatible learning was to identify and present the underlying principles that an educational intervention has to adhere to in order to be considered 'brain-compatible'. Since the delivery medium of the proposed educational intervention will be via blended learning technologies, the subsequent section will then review blended learning. Finally, the specific fundamental programming concepts that are used in this study, as well as their overall role in programming education in general, was briefly reviewed.

2.2 Learning Theories and Principles

Systematic studies of human behaviour, including studies of how people learn, is a relatively new field of scientific enquiry (Ormrod, 2011). However, despite the youth of this field, many studies have already been dedicated to investigating how learning takes place. During such studies researchers strive to identify recurring patterns in the data and to make generalizations based on these patterns. Such generalizations lead to the formulation of *learning principles* and *learning theories*. Learning principles identify the factors that influences learning. For example, the **principle** that a behaviour which is rewarded in some way is more likely to re-occur in future than one which is not followed by a reward. A learning **theory** on the other hand aims to provide an explanation of the underlying mechanisms that are involved in learning. Thus, whilst a learning principle presents *what* factors are important, a learning theory would explain *why* those factors are important (Ormrod, 2011). Learning **principles** do not change much over time, however, learning **theories** have continually changed as understanding of human behaviour evolved (Ormrod, 2011). A few well known examples of learning theories include:

Behaviourism

This theory stems from some of the earliest attempts to study human learning with some degree of scientific rigour. Behaviourism focussed on the study of behaviours (*response*s) and the environmental factors (*stimuli*) that preceded those behaviours. Events were only deemed important if they could be observed. This lead to the belief that learning could only happen if the learner was actively engaged in the learning process (Mitchell, Myles, & Marsden, 2013; Ormrod, 2011).

Social learning theory

This theory attempted to address some of the limitations of behaviourism and added the premise that humans can also learn through watching and imitating others (Huitt & Monetti, 2008; Ormrod, 2011).

Cognitivism

Cognitivism provides a theoretical model for understanding the internal thought processes of humans. This theory stems from the realisation that observable behaviours alone cannot account for all aspects of learning. Instead, human cognition (internal thought processes) also has to be taken into account. Many important theorists contributed to early work that lead to the development of cognitivsm. For example the work of Piaget, that dealt with the importance of early childhood development in cognition, and the work of Vygotsky, that introduced concepts such as scaffolding, whereby cognitive abilities are incrementally developed to enable the learner to deal with progressively more difficult concepts (Vygotsky, 1978).

Social cognitive theory

This theory expanded on social learning theory through the addition of the interpretation of observational learning in terms of cognitive processes. The theory recognises that people can control their own learning (Mitchell et al., 2013; Ormrod, 2011).

Social cultural theory

This theory deals with the ways in which a society's adults and cultural creations (for example schools) can enhance cognition and pass accumulated wisdom along to children (McInerney, Walker, & Liem, 2011; Ormrod, 2011).

The above overview of theories is not intended to be complete. Rather, it serves to highlight the two most important shortcomings of learning theories.

Firstly, no single learning theory can be deemed complete. Most such theories focus on a few specific aspects of learning only.

Secondly, newer learning theories usually stem from prior theories. These pre-existing theories usually have a pre-existing support base and there might thus be an inherent bias which could prevent the acceptance of completely new ideas.

The same shortcomings does not, however, exist for most learning principles. As mentioned before, learning principles focus on *what* works in an educational setting and not *why* it works. Principles thus focus on the cause-and-effect relationship between events and subsequent learning. This relationship does not change much. Ormrod (2011) presents the example of the 'reward principle', that was introduced more than a 100 years ago by Thorndike, to demonstrate how enduring these principles can be. In contrast to this principle, "Thorndikes original theory of why reward affects learning, however, has largely been replaced by other explanations" (Ormrod, 2011, p. 6). For this reason, it is generally a good idea for pedagogical approaches to focus on incorporating appropriate learning principles into teaching practice, instead of only subscribing to a specific learning theory. One such principles-based learning approach is brain-compatible education.

2.3 Brain-compatible education

Brain-compatible learning is an approach to education which is based on the underlying "biology of learning" instead of "simply following traditional practices" (McGeehan, 2001, p. 9). As noted earlier, this educational approach stems from a combination of neuroscience and educational psychology and was first made possible by advances in brain imaging during the 1990s (McGeehan, 2001). The term 'brain-compatible learning' was first coined by Leslie Hart in 1983 in his book Human Brain and Human Learning to refer to education designed to match "settings and instruction to the nature of the brain, rather than trying to force [the brain] to comply with arrangements established with virtually no concern for what this organ is or how it works best" (McGeehan, 2001, pp. 7-8).

Brain-compatible, or brain-based, learning is not a formalised education approach or 'recipe for teachers', instead it provides a "set of principles and a base of knowledge and skills upon which we can make better decisions about the learning process" (Jensen, 2008, p xiii). Brain research has shown that humans literally grow new dendrites and neural connections every time they learn something and knowing which educational activities are the most effective in stimulating such growth allows educational practitioners to create material that leverage the way the brain naturally learns (Lombardi, 2008). Through such knowledge the educational process could be significantly enhanced for most students (Taylor, 2008). A *complete* understanding of the underlying biological processes of learning is not needed to be able to *apply* brain-compatible learning principles. However, some insight into how such learning works at a biological level can aid in understanding the reasons for these principles.

2.3.1 How the brain learns

The human brain consist of a vast network of braincells known as *neurons*. There are many types of neurons but they all share a similar basic structure as shown in figure 2.1. Each neuron consists of a cell body from which many fibre-like growths called *dendrites* extend. There is also a single long fibre known as the *axon* that terminates in a lot of smaller fibres known as *teledentrites* or processes. At the end of each *process* is a small bulb known as a *synaptic terminal* or *synapse*. Synaptic terminals are filled with chemical compounds known as *neurotransmitters* (Smilkstein, 2003; Jensen, 2008).

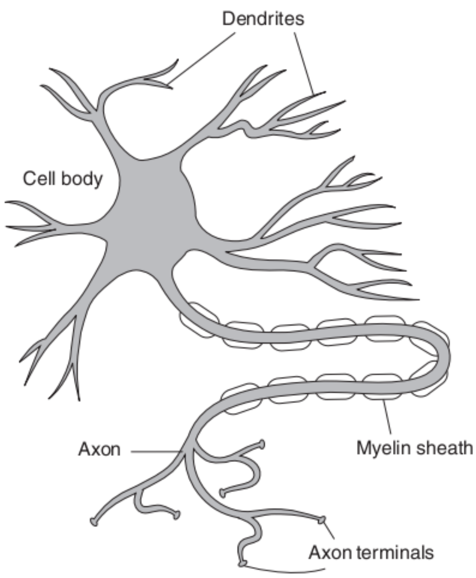

Figure 2.1: Neuron (from Jensen (2008, p. 14))

During the process of learning neurons will grow new dendrites *specific to the new learning* (Smilkstein, 2003). The axons of other neurons will connect to these new dendrites at the synapses.

From this perspective learning *is* the growing and connecting of dendrites (Smilkstein, 2003; Jensen, 2008; Bjorklund, 2012). This *growing and connecting* process results in networks of connected neurons as shown in Figure 2.2. The number of neurons in a human brain can vary from 10 billion to 100 billion neurons (Kolb, Gibb, & Robinson, 2003). These neurons are connected to each other forming large neural networks. A single neuron might be connected to as many as 10 000 other neurons (Smilkstein, 2003; Sousa, 2006).

However, learning goes beyond just the *formation* of new synaptic connections, the newly formed connections are also often removed in a process known as *pruning*. Thus, every new experience will result in the growth of

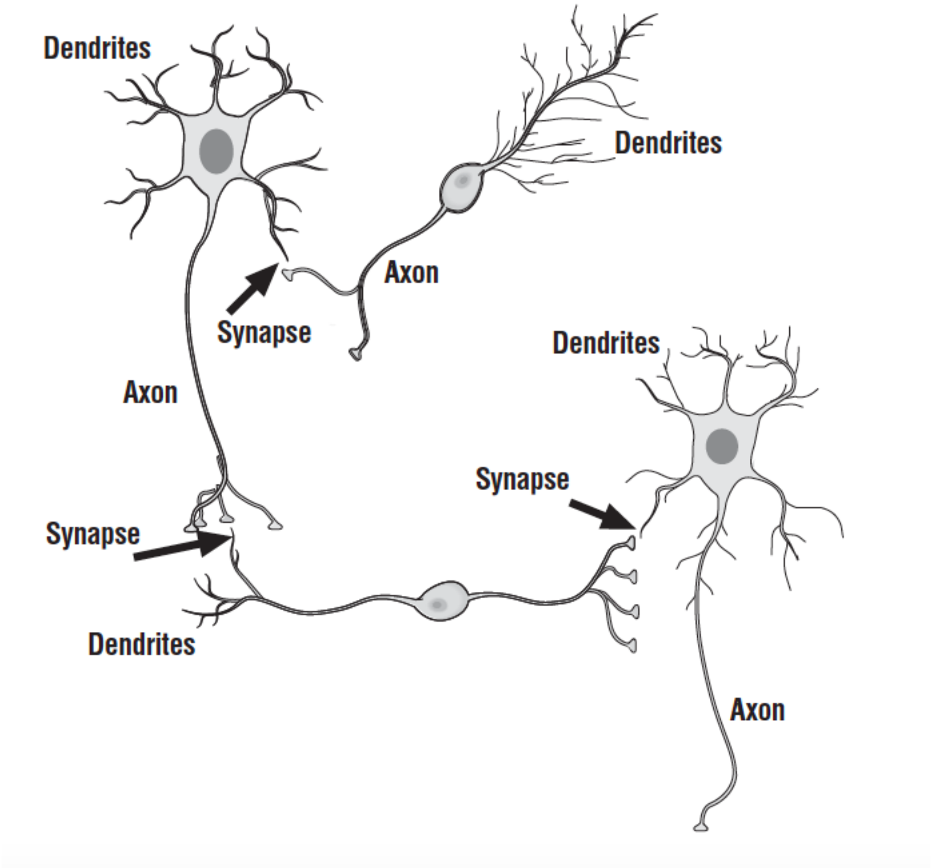

Figure 2.2: Neurons connecting (adapted from Jensen (1998, p. 12))

new brain structures, but if these new structures are not subsequently used, or practiced, the brain will remove them by pruning (Smilkstein, 2003). The brain can be said to be economical (Smilkstein, 2003). Conversely, every time a new or existing structure **is** used the formed pathways is *reinforced*. This tendency of the brain to reinforce exiting learning every time it is used was first theorized by Donald Hebb who stated:

"When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased" (Hebb, 1949, p. 62).

In other words: Every time a specific skill or knowledge item is used certain neurons in the brain sends out an electro-chemical pulse which travels along the dendrites to connected neurons. This pulse is also described as *firing*, or *activating*, the neuron. Other neurons connected to the neuron that fires may or may not fire in response to its activation.

This activation process not only gives rise to the resulting actions and thoughts, but also causes the brain to *reinforce* the connection between the neurons that fired in order to elicit that action or thought.

Hebb (1949) described this effect of repetition as inducing lasting cellular changes that add to the stability of the specific neural network. Thus, learning that is used frequently will persist for much longer than learning that is used only a few times before the brain ultimately prunes it.

The overall process whereby the brain continuously grows and prunes neural networks is also often referred to by the term *neuroplasticity* or just *plasticity* of the brain. Neuroplasticity, the process whereby "the human brain continually reorganizes itself on the basis of input" (Sousa, 2006, p. 5), forms the basis for all learning.

As mentioned above, studying the link between specific educational practices and actual growth and persistence of dendrites, synapses, and neural networks only became possible in the 1990s due to advances in brain imaging technology. Since then many learning principles have been studied and identified as being 'brain-compatible'. The following sub-section will briefly overview some of these principles.

2.3.2 Brain-compatible learning principles

As mentioned before, brain-compatible learning stems from a combination of educational psychology and neuroscience. Various brain-compatible learning principles were derived through observing actual physiological changes in the brain (neuroscience) as a result of specific educational interventions (educational psychology). The use of many of these brain-compatible learning principles in education is not new. According to Erlauer (2003) every successful teacher already uses certain brain compatible principles effectively. However, as mentioned above, the direct evidence demonstrating the physiological effect that using these principles have on the learner's brain was only made possible due to recent advances in brain imaging technology.

Currently, no single authoritative list or taxonomy exists that describes and encompasses all known brain-compatible learning principles, instead various authors present different principles (Fogarty, 2009; Jensen, 2008; Materna, 2007; Sousa, 2006; Craig, 2003; Smilkstein, 2003; Caine & Caine, 1991). There is, however, a significant overlap between the principles presented by these authors. Table 2.1 provides a list of some of these principles.

Table 2.1: Summary of brain-compatible learning principles

Principles	**Authors**
There is no long term retention without rehearsal	Fogarty (2009), Jensen (2008), Materna (2007), Sousa (2006), Smilkstein (2003)
Short, focused learning activities are best	Jensen (2008), Sousa (2006)
Learning Is enhanced by challenge and inhibited by threat	Fogarty (2009), Jensen (2008), Craig (2003), Caine and Caine (1991)
Emotions affect learning (patterning)	Fogarty (2009), Materna (2007), Craig (2003), Smilkstein (2003), Caine and Caine (1991)
Learning involves both focused attention and peripheral perception (Learning experiences should be multifaceted)	Fogarty (2009), Jensen (2008), Materna (2007), Craig (2003), Caine and Caine (1991)
The brain has a spatial memory system and a set of systems for rote learning (The brain has separate implicit and explicit memory systems)	Fogarty (2009), Caine and Caine (1991)
The brain simultaneously perceives and processes parts and wholes	Fogarty (2009), Craig (2003), Caine and Caine (1991)
Learning engages the entire physiology (A healthy lifestyle promotes learning)	Fogarty (2009), Jensen (2008), Materna (2007), Craig (2003), Caine and Caine (1991)
The brain is a parallel processor (Multitasking)	Fogarty (2009), Jensen (2008), Craig (2003), Caine and Caine (1991)
Learning is embedded in natural and social settings	Fogarty (2009), Caine and Caine (1991)
Each brain is unique	Fogarty (2009), Jensen (2008), Craig (2003), Caine and Caine (1991)
The search for meaning is innate	Fogarty (2009), Jensen (2008), Craig (2003), Caine and Caine (1991)

Continued on next page

Table 2.1 – continued from previous page

Principles	Authors
The search for meaning occurs through patterning	Fogarty (2009), Jensen (2008), Craig (2003), Caine and Caine (1991)
Learning always involves both conscious and unconscious processes	Fogarty (2009), Materna (2007), Caine and Caine (1991)
Learning with specific context is best	Jensen (2008), Craig (2003)
Learning is the process of forming novel neural networks or patterns	Craig (2003), Smilkstein (2003)
Novel patterns can only form as extensions of existing patterns	Materna (2007), Sousa (2006), Craig (2003), Smilkstein (2003)
Learners need to recognize and connect patterns by themselves (Learning only happens from what is actively, personally, and specifically experienced)	Jensen (2008), Materna (2007), Craig (2003), Smilkstein (2003)
Learners should be given choices to accommodate different learning styles (Lessons should be multifaceted)	Jensen (2008), Materna (2007), Craig (2003)
Learning must apply to real life experiences(context) of learners	Jensen (2008), Materna (2007), Craig (2003)
Immediate feedback amplifies learning	Jensen (2008), Craig (2003)
Learning is collaborative and influenced by interactions with others	Materna (2007)

Some of the principles shown in Table 2.1 would be difficult to control for in a blended learning, or even in a classroom, environment. For example, knowing that a healthy lifestyle promotes learning is something that can be communicated to students but that cannot necessarily be controlled by the instructional designer. Similarly, the understanding that learning is the process of forming novel neural networks or patterns can enhance a learner's understanding of how his/her own brain works, and can even be used to combat certain fixed mindsets that could have a negative impact on learning, but does not otherwise practically affect instructional design (Smilkstein, 2003).

In other cases, the practical implication of some of the principles list in the table might be such that they can be sensibly combined into a single discussion. In these cases, such a combined discussion will be presented. For example, the principle that learning is collaborative and influenced by interactions with others, can be seen as a consequence of several of the other principles and thus does not necessarily warrant in depth discussion separate from these other principles. Therefore, the subsequent subsections will provide more in depth discussion on many of these principles, but will exclude such discussion for principles which, in the researcher's opinion, could not be meaningfully used in the design of the research intervention for the current study, or that has already been dealt with as part of the discussion of another, more fundamental principle.

Novel patterns can only form as extensions of existing patterns

According to Smilkstein (2003, p. 71) "dendrites, synapses, and neural networks grow only from what is already there." When we learn, neurons are constantly connecting and disconnecting from each other. However, not all such connections are to other neurons that form a part of a network that is *relevant* and thus have *meaning* in the context of the new knowledge. When a connection to *relevant* structures forms, the new connection acts to further strengthen the existing network (Jensen, 1998). Connections to neurons that are not relevant in the specific context are pruned. Every time prior learning is activated the brain is more likely to make a connection to the new material, which would lead to increased comprehension and understanding (Jensen, 2008). Thus in order to teach something new, the new knowledge has to connect to the learners' past experiences (Sousa, 2006). Linking to something familiar act as a foundation for the new knowledge (Smilkstein, 2003).

Short, focussed learning activities are more effective

During any learning experience, the material that is presented first, will be remembered the best (Sousa, 2006). Whilst, information that is presented last will be remembered second best, and the middle of the lesson will be remembered the least (Sousa, 2006). This is known as the *primacy-recency* effect and is caused by the brains limited 'working memory'. A brain can only handle a certain amount of information at the same time. Jensen (2008) recommends limiting cognitive activities to periods of 5 to 10 minutes each. In this way, the amount of 'low impact' learning in the middle of a lesson is minimized. A large part of what students learn is presented too fast to be processed consciously and the brain thus needs additional time to allow it to process the information and determine how meaningful it is (Jensen, 2008). Therefore "learning is best when focused, diffused, and then focused again" (Jensen, 2008, pp. 28).

There is no long term retention without rehearsal

"Retention refers to the process whereby long-term memory preserves a learning in such a way that it can locate, identify, and retrieve it accurately in the future" (Sousa, 2006, p. 86). Because the brain constantly forms new connections, many of these connections lack meaning and are thus unnecessary. The brain therefore constantly *prunes* such unneeded connections. Conversely, if the connection is considered meaningful, or is used several times, the brain reinforces the connection every time it is re-used. "Over the long term, repeated practice causes the brain to assign extra neurons to the task, much as a computer assigns more memory to a complex problem" (Sousa, 2006, p. 97). Once a person stops doing something (stops using the connections), the learning will eventually be forgotten due to the brain pruning the unused connections, even if they relate to useful knowledge. This is why, for example, a student might no longer remember the learning from a specific course after an extended holiday (Smilkstein, 2003; Sousa, 2006). It is also important to understand that unguided practice is not necessarily a good thing. "Practice does not make perfect. Practice makes permanent" (Sousa, 2006, p. 97). In order for practice to lead to improved learning the learner must be able to analyze the results of the application of the learning and know what to change in order to improve future performance (Sousa, 2006). Practice should thus be accompanied by *feedback* that is constant, consistent, and specific to ensure that practice that is permanent is also correct (Fogarty, 2009, p. 112). The effect of feedback is also amplified if it is immediate (Craig, 2003; Jensen, 2008).

Emotions affect learning

"Emotions produce chemicals that enter the brain and physiologically affect the synapses and, consequently, the brain's ability to think, learn, and remember" (Smilkstein, 2003, p. 86). According to Fogarty (2009) the affective and cognitive domains are interconnected in such a way that it is essential to consider the impact emotions will have on learning. Emotions can have either a negative or a positive impact on learning. Negative emotions will impede learning whilst positive emotions will motivate students and promote learning. Emotions help learners to determine what to believe or disbelieve, and what to store for long-term retention (Jensen, 2008). They also help learners make faster decisions using unconscious judgements, and to make better decisions by engaging values (Jensen, 2008). “Emotions engender focused attention. Attention engenders short-term memory. Short-term memory engenders long-term memory” (Fogarty, 2009, p. 24). “Emotions are crucial because they focus our attention, which in turn drives our learning and memory systems” (Scoffham, 2004). Therefore students are more likely to remember information that is meaningful to them and that contains an emotional ‘hook’ they can relate to (Banikowski, 1999).

Learning is enhanced by challenge and inhibited by threat

“Dendrites, synapses, and neural networks grow from stimulating experiences” (Smilkstein, 2003, p. 71). The natural learning process is often driven by curiosity. “The brain loves a challenge and by nature is compelled to engage when a challenging puzzle, riddle, problem, or conundrum is presented” (Fogarty, 2009, p. 24). If students are presented with an interesting problem in a non-threatening way they will automatically try to solve that problem. However, if the learning environment itself is stressful or threatening learning will be less than optimal. A *perception of threat* causes the individual’s brain to ‘downshift’ due to the release of chemicals that can impair memory and learning (Caine & Caine, 1991; Tompkins, 2007). A perceived threat, either physical or psychological, triggers a *fight or flight* response which closes connections to the prefrontal cortex, which in turn impairs logical thinking (Tompkins, 2007). Learning is thus dependent on the learner feeling secure and not perceiving any threats (Jensen, 1998, 2008). What constitutes a threat will also differ from person to person, since a threat is *anything* that could trigger a sense of helplessness (Caine & Caine, 1991). A learner with adequate prior or foundational knowledge might perceive a given problem as challenging, whilst one without sufficient prior knowledge might perceive the same problem as threatening.

Learning experiences should be mulitfaceted

Learning involves both focused attention and peripheral perception (Caine & Caine, 1991; Fogarty, 2009). According to (Erlauer, 2003) a large part of what a learner learns comes from the surrounding environment and not from the teacher. Things the learner perceives peripherally enters the learners brain without direct conscious consideration (Caine & Caine, 1991). Thus, even whilst attention is focused on a specific task the brain is aware of other peripheral sensory (visual, kinaesthetics, etc.) inputs and every time the learner momentarily loses concentration, the brain might engage with the surroundings and environment (Fogarty, 2009). The brain thus engages in both *focused attention* and *peripheral perception* during most learning activities. Focused attention is where the brain is focused and alert and ready to connect to the new information. Peripheral perception means that the brain is subconsciously aware of a wide variety of peripheral, sensory inputs. These can include all the senses - visual, auditory, olfactory, kinesthetic, and taste. Engaging both visual and verbal faculties in a lesson will encourage meaningful learning (Lombardi, 2008). Often the peripherally sensed stimuli become intricately linked to the memories and learning formed. For example, there is a well established link between the sense of smell and the evocation of childhood memories (Willander & Larsson, 2006). Instructional designers should thus be aware that the brain will respond to the entire context in which teaching or communication occurs (Caine & Caine, 1991). The brain is a massively parallel system and continuously processes inputs from all the senses simultaneously. Thus the brain could process visual or auditory inputs in the parietal lobes whilst using the frontal lobes for thinking or problem solving. "Promoting activities that activate seeing, hearing and feeling facilitates much more productive, efficient and long lasting learning" (Materna, 2007, p. 52). "Experiences that provide rich sensory input well beyond the capacity of a book or a worksheet have the greatest chance of sparking dendritic growth and increased synaptic connections" (McGeehan, 2001, p. 10).

The brain processes parts and wholes simultaneously

The human brain can only handle a limited amount of facts simultaneously in its working memory (Sousa, 2006). It also only stores information that it considers to be meaningful (Caine & Caine, 1991; Fogarty, 2009). According to Banikowski (1999) people learn "by organizing new information into hierarchies and organizing information so that the relationships between isolated bits of information can be detected". The brain therefore need to discern how low level detail data fits into the bigger picture in order to assess the meaningfulness of such data. The brain "analyses the discrete parts of information and at the same time discerns the big-picture look at the information" (Fogarty, 2009, p. 24). Learning is a whole brain activity involving both the left and right hemispheres of the cerebral cortex. The right hemisphere will analyse the bigger holistic picture whilst the left hemisphere process the detail more analytically. Both hemispheres are however intricately linked and in constant communication with each other (Fogarty, 2009). Lessons that highlights the role of detailed material in its broader context should thus be more successful than those dealing with such detailed material without providing the larger context.

The brain has separate implicit and explicit memory systems

The human brain has both explicit and implicit memory systems. The implicit memory system deals with information that can be related directly to actual life experiences. Memories formed by the implicit system tend to be episodic-, emotional-, or spatial-experiential memories and form long term memories automatically (Caine & Caine, 1991; Fogarty, 2009; Sousa, 2006). The explicit system, on the other hand, requires practice, repetition, and rehearsal before memories will be retained long term. Memories formed by the explicit system could be semantic (factual content) or procedural (muscle memory), and in some cases also episodic (context) (Materna, 2007). Learning semantic content, despite being necessary to advance knowledge, is often unexciting and relies on the explicit system. In order to improve long term retention of such learning Materna (2007) recommends that educators try to engage multiple memory pathways when presenting the knowledge. Learning should be presented in a format that is multi-sensory, for example it can include a discussion, visuals, and hands-on activities (Materna, 2007). "Actively engaging the learners in applying the information (procedural) in collaborative work groups (episodic) within an enjoyable and non-threatening setting (emotional) will promote a greater chance of activating multiple pathways and satisfying criteria for transfer to long-term storage" (Materna, 2007, p. 35).

Learning is embedded in natural and social settings

"Learning is most powerful when it is embedded in an experience that affords dialogue and discussion" (Fogarty, 2009, p. 26). As mentioned above, engaging learners in applying knowledge in collaborative workgroups within an enjoyable, non-threatening environment will engage procedural-, episodic-, and emotional-memory pathways simultaneously. Humans learn best from having experiences and talking about the experiences. Remembering the experience itself also allows the learner to access spatial memory (when and where the experience happened), whilst talking about the experience uses cognitive memory (Fogarty, 2009).

Each brain is unique

Every human is shaped by different experiences growing up. Every person has read different books, been to different places, and understand concepts in different ways and to different degrees (Fogarty, 2009). There are also general differences between the brains of males and those of females (Jensen, 2008, p. 35). Every student therefore has a unique brain, with unique strengths, and a unique prior knowledge schema. This means that the same lesson will be experienced differently by different learners. In some cases an instructional designer might be able to plan ahead for such differences. For example; students from different cultural or language backgrounds might experience the same lessons in different ways, and such cultural differences can sometimes be anticipated. In other cases it might be more difficult to anticipate differences. It is however essential to keep these differences in mind. What one student find challenging might induce stress for another. What one considers fun, might be boring and too easy for another.

The search for meaning is innate

Whether or not a particular piece of information is considered *meaningful* has a major impact on whether or not that learning is retained. Learning will only happen if the learner finds the content of a lesson sufficiently meaningful and therefore actively engages in the learning experience (Scoffham, 2004; Rogers & Renard, 1999; Caine & Caine, 1991). According to Caine and Caine (1991) this search for meaning is a survival mechanism that has its roots in human evolution. It is thus a fundamental part of every human's brain. It is however important to realize that *what* is considered meaningful, and thus stored effectively, will also largely depend on the learner's own perspective (McGeehan, 2001). The purpose of the human brain is to understand the world. The brain is thus acts as a "meaning-making machine, designed to make sense of all the sensory input it receives and create meaning of the world around it" (Fogarty, 2009, p. 26). Every time a person is presented with a challenge or a problem the brain will automatically attempt to solve the problem. Simultaneously, whilst the brain is busy solving a particular problem, it also builds experience, practice decision making, improve explicit thinking skills, and generally learns to be better at solving that type of problem in future (Fogarty, 2009).

The search for meaning occurs through patterning

The way in which the brain determines the meaningfulness of a new piece of information is known as patterning. Essentially the brain analyses incoming information and searches for recognizable patterns in the new information. It then uses these patterns to try to fit the new information into its existing schema of how the world works (Caine & Caine, 1991; Fogarty, 2009). During this process of trying to fit new information into its existing schema the brain naturally integrates and assimilates information. At the same time the brain, through pruning, resists the imposition of meaningless patterns into the schema (Caine & Caine, 1991). This process takes time and the exact duration of time needed for a pattern to integrate and a lesson to 'sink in' will vary from learner to learner. However, "once learners have experienced learning in their preferred modality the right number of times and for the right length of time, they will feel that it is now true. When this happens, we believe it in our gut. Until then, its only data with little meaning" (Jensen, 2008, p. 92). Effective lessons will thus also give learners both the time and the opportunity to make sense of their experiences through reflection in order to find and construct meaningful connections (Gülpinar, 2005).

Learning always involves conscious and unconscious processes

Many of the most important processes involved in learning happens while the learner sleeps (Fogarty, 2009). During sleep the brain does the processing required to connect different knowledge items and to store items in long-term memory for later recall. Similarly, other unconscious processes play important roles in learning. Unconscious processes range from the registration of sensory information to the activation of associative memory networks, including beliefs and value systems that might influence learning (Kuldas, Ismail, Hashim, & Bakar, 2013). Conversely, conscious processes allow a learner to active pay attention to a specific lesson, or to notice similarities between the new material and existing facts consciously (Kuldas et al., 2013).

Learners need to recognize and connect patterns by themselves

"Dendrites, synapses, and neural networks grow from what is actively, personally, and specifically experienced and practiced" (Smilkstein, 2003, pp. 71-72). It is essential for learners to actively participate during their own learning. According to Caine and Caine (1991) such participation could take the form of talking, listening, reading, viewing, acting, and valuing. Actively experiencing and participating in the application of the concepts that are being taught also greatly enhances the learner's ability to find meaning in a lesson. "Learning that starts with a 'being-there' experience gives added power to all other kinds of input; whether it be immersion, hands-on with real objects, hands-on with models, second hand, or symbolic understanding" (McGeehan, 2001). During active engagement in a related activity, neurons that are specific to the learning associated with that activity begins to grow (Materna, 2007). More novel and stimulating active learning environments also lead to substantially greater growth in neural structures than nonstimulating and inactive environments (Materna, 2007). According to Gülpinar (2005) the educator should strive to create an 'orchestrated immersion'. This is achieved by creating a complex experience which involves all the sensory channels to create optimal opportunities for learning by providing learners with rich, complex and realistic experiences (Gülpinar, 2005; Caine & Caine, 1991).

2.3.3 Implications for online and blended learning

The effectiveness of brain-compatible approaches has, despite some criticisms, been proven (Winters, 2001), which, together with the above discussions of various brain-compatible learning principles, provide the theoretical basis that informed the specific design decisions made during the construction of the educational intervention used in this research.

Since their inception, brain-compatible learning techniques have been used extensively in classroom environments and many practical guidelines given for the adoption of brain-compatible principles are specific to classroom environments (Taylor, 2008; Smilkstein, 2003). However, very little research exist relating to the use of such principles in the e-learning component of a blended learning environment.

Many of these principles apply specifically to classroom instruction, for example principles dealing with the effect of ambient lighting on learning (Jensen, 2008). However, it could be argued that most of the brain-compatible learning principles identified by previous researchers for classroom activities can *also* be used in the implementation of e-learning-based learning materials (Reid & Van Niekerk, 2014). For example, research related to the effect that using specific colours have on learning (Bradshaw, 2003), should be relevant, irrespective of whether these colours are used on a printed medium, or on a Web page. Similarly, the principle that 'short, focussed learning activities are best', should apply equally to both classroom activities and online activities. The exact duration of such an activity that would be considered *ideal* might perhaps vary, especially if a specific learner has a preference for one modality over another, but the general principle that a shorter activity is better than a long one would still be true.

This research uses a blended learning approach whereby an online, e-learning, intervention is used to augment classroom instruction. The following section will therefore briefly introduce the field of blended learning, with a specific focus on the reasons for choosing a blended learning approach.

2.4 Blended learning

As many different terms are commonly used to refer to educational approaches that uses computer-based technology to deliver learning material, it is important to understand the differences between the most commonly used terminology. Commonly used terminology includes *e-learning*, *blended learning*, *online learning*, *web-based learning*, *mobile learning*, and *computer aided instruction*. For the purposes of this dissertation the term *e-learning* will be used to refer to *any* instructional approach that include computer based delivery mechanisms. Usually, *online-* and *web-based*, learning is be used to refer to e-learning that specifically makes use of web-based technologies to deliver instruction. However, in this dissertation the use of the Web as a delivery platform will be assumed, and the term e-learning will thus also be used to refer to such technologies. Finally the term *blended learning* (which some authors refer to as "hybrid learning") refers to learning and/or teaching approaches where online and/or e-learning components are combined (hence *blended*) with more traditional approaches, such as face-to-face instruction, to provide an enhanced learning experience (Means et al., 2009; Graham, 2006). In this dissertation the term *blended learning* will specifically refer to the use of e-learning material to *augment* instruction that was delivered in a face-to-face classroom setting.

Despite the fairly broad nature of the above definitions, it would be a mistake to simply view *any* learning content in an electronic form as e-learning. Simply publishing a lecturer's presentation slides to an online platform, for example, should not be considered a form of e-learning. It is also important to not simply devolve the development of an e-learning system into a purely technical exercise as this might result in an expensive software implementation that does not deliver much learning value (Ismail, 2002). Furthermore, the simple definition of the term blended learning, does not account for the vast range of ratios between face-to-face and e-learning that could constitute a blended learning environment, or the virtually limitless design possibilities, or its applicability to so many different contexts (Garrison & Kanuka, 2004; Osguthorpe & Graham, 2003). Blended learning designs can range from almost entirely face-to-face learning to almost fully online learning (Graham 2006). It is also common for blended learning approaches to include a variety of learning resources and communications options (Harding, Kaczynski, & Wood, 2012).

Through the use of blended learning the learners can gain the conveniences that is offered by online courses without losing face-to-face contact. This leads to a learning experience that is richer than either traditional face-to-face instruction or online courses (Harding et al., 2012). As such, blended learning approaches offers many benefits.

2.5 Benefits of Blended and/or E-learning

Providing learning opportunities in an e-learning, or blended learning, format holds many advantages for all the stakeholders involved in these learning programmes. These advantages can be loosely categorized according to the specific stakeholders who benefit as follows:

Firstly, e-learning approaches hold many advantages for the learners themselves (Bognar, Gajger, & Ivic, 2015; Akbulut & Cardak, 2012; Harding et al., 2012; El-Hussein, M., Cronje, & C., 2010; Bell, 2007; Zhang, Zhao, Zhou, & Nunamaker, 2004; Nisar, 2002; Brusilovsky, 2003). These include, but are not necessarily limited to:

- material can be used as self-study, with or without tutor support, or in blended environment (Nisar, 2002)
- learning material often has a hyper-linked nature which allows learners to explore related topics of interest (Brusilovsky, 2003)
- learning can be enhanced and be more flexible (for example through adaptive features) (Nisar, 2002)
- time spent on training is significantly reduced (Nisar, 2002)
- learning is independent of time and place (can be done any time and any place where the learner has access to a suitable device), and learners can access it an unlimited number of times (El-Hussein et al., 2010; Zhang et al., 2004; Nisar, 2002)
- training material is of a consistent quality (human lecturers might have bad days) (Nisar, 2002)

- learning is learner-centered and self-paced (Zhang et al., 2004; Nisar, 2002)
- student support systems are often better (includes instant feedback and/or topic specific help) (Nisar, 2002)
- learning environment is anonymous and there is less pressure to perform well in front of peers (Bell, 2007)
- anonymous learning environments also allow the exploration of more personal issues (Bell, 2007)
- adaptive features could support preferred learning styles, allow for learner's past experience, individual traits, specific learning needs, etc. (Brusilovsky & Millán, 2007; Akbulut & Cardak, 2012)
- training is available when and where required at a time and place that is convenient to the learner (Bell, 2007)
- learning environments provide flexible opportunities for participation in collaborative work (Bognar et al., 2015)

The second major stakeholder would be the educational institution itself. From an institutional viewpoint, e-learning also offers many advantages (Ferguson, 2012; Long & Siemens, 2011; Bell, 2007; Unneberg, 2007; Pollitt, 2008; Salmon, 2005; Zhang et al., 2004; Deeny, 2003; Welsh, Wanberg, Brown, & Simmering, 2003; Nisar, 2002; Young, 2002). These include:

- cost savings - e-learning based training solutions can lead to reduced infrastructure costs and are also inexpensive to distribute and administer from a centralized point. This also means that it would be very easy to maintain, manage and update training materials.(Unneberg, 2007; Salmon, 2005; Nisar, 2002; Welsh et al., 2003)
- participation in learning programs can easily be checked and monitored (Nisar, 2002). Monitoring is especially important from a legislatory compliance point of view (Bell, 2007) and online participation includes detailed reports on when and where training took place, how much time was spent, how the employee performed in the assessments, etc.

- learning analytics can be used for the early identification of students at risk of dropping out or failing (Ferguson, 2012; Long & Siemens, 2011)
- course materials can be constantly updated, which can ensure that distributed course content is always current and relevant (Bell, 2007; Young, 2002)
- training can complement existing knowledge management processes and materials can be archived for reuse (Young, 2002; Zhang et al., 2004)
- e-learning can reduce the impact of staff turnover (Deeny, 2003)
- material can be globalised, i.e. translated into many languages, and the student can switch between alternative languages at will, which allows better support for second language learners, the reuse of existing material, and once again leads to cost savings (Pollitt, 2008; Bell, 2007)
- material can potentially be offered to global audiences, for example in the form of a Massive Online Open Course (MOOC) (Zhang et al., 2004)
- anonymous training environments can allow the exploration of issues relating to ethics, or other sensitive/personal matters.

While, the design and implementation of any instructional program requires a significant investment in time from course and/or content creators, e-learning offers many benefits to the course/content creators involved in such a program (Clark, 2007; Liaw, Huang, & Chen, 2007; Zhang et al., 2004; Brusilovsky, 2003; Ismail, 2002). These benfits are:

- electronic and/or web-based media are very *rich*. This means that educational material developed in these types of media is not restricted to simple text and static graphics, but can consist of a mixture of text, graphics, animations and even sound or video clips (Zhang et al., 2004)
- e-learning training materials can include programmatic components, which could allow virtually limitless customization (Brusilovsky, 2003).

- wikis, blogs, podcast, e-portfolios, etc. allow instructors a variety of tools. Furthermore, new technologies are constantly emerging, which provides course designers with a great deal of creative freedom (Clark, 2007; Liaw et al., 2007)

- learning design systems allow the use of content creators who are not familiar with a specific pedagogical approach (IEEE 1484.1, 2003; Ismail, 2002)

- existing material can easily be re-used or even re-purposed to meet new training needs (Zhang et al., 2004)

- the ability to rapidly distribute new material also allows more time spent on the actual *creation* of content, and less on administrative tasks

Many of the benefits listed above might seem 'obvious', however, blended and e-learning also has some less obvious benefits. These relate specifically to improvements in learning from a strictly pedagogical point of view. From a purely educational point of view, it is these pedagogical benefits that should carry the most weight in a decision to make use of blended and/or e-learning.

2.5.1 Pedagogical benefits of Blended and/or E-learning

Since the first computer aided instruction systems appeared, many researchers have conducted studies to compare the effectiveness of these 'new' approaches to more traditional classroom based instruction approaches. Such research papers would thus be the most appropriate sources to evaluate whether or not blended and/or e-learning approaches offer a pedagogical advantage over traditional instruction approaches. The United States Department of Education published a report based on a meta-analysis of the results of more than 1000 such empirical studies that were published from 1996 through July 2008 (Means et al., 2009). The report focuses predominantly on publications after 2004 which compares the effectiveness of various forms of e-learning and blended learning to face-to-face education (Means et al., 2009, p. xiii) and was thus considered to be an ideal source to provide insight into the effectiveness of blended and/or e-learning approaches.

The report by Means et al. (2009) examined 51 identified study effects, of which 44 were drawn from research focusing on older (adult) learners. This focus on older learners is thus of particular importance to tertiary educators, who work exclusively with adult learners. Adults are more set in their ways than children and already have well-established values, beliefs, and opinions. Adults relate new information and knowledge to previously learned information, experiences, and values which might result in misunderstanding (Wilson, Zafra, Pitcher, Tressler, & Ippolito, 1998).

The following key-findings are of specific importance for the purposes of this dissertation (Means et al., 2009, p. xiv-xvi):

- "Students who took all or part of their class online performed better, on average, than those taking the same course through traditional face-to-face instruction"
- "Instruction combining online and face-to-face elements had a larger advantage relative to purely face-to-face instruction than did purely online instruction"
- "The effectiveness of online learning approaches appears quite broad across different content and learner types."
- "Most of the variations in the way in which different studies implemented online learning did not affect student learning outcomes significantly."
- "Effect sizes were larger for studies in which the online and face-to-face conditions varied in terms of curriculum materials and aspects of instructional approach in addition to the medium of instruction."
- "Online learning can be enhanced by giving learners control of their interactions with media and prompting learner reflection."
- "Providing guidance for learning for groups of students appears less successful than does using such mechanisms with individual learners."

From a purely pedagogical viewpoint the findings in Means et al. (2009) are very important for this study. Firstly, the findings show that a *blended approach*, where e-learning and face-to-face instruction are combined, is the most effective educational approach. However, if such a blended approach is not possible, a purely e-learning based approach would in fact still be better than classroom instruction alone (Means et al., 2009). It can thus be argued that it is imperative for tertiary educators to explore the use of blended learning in their own subject offerings, even if those subject offerings are still predominantly classroom based. "No longer is it sensible to ask the question 'Why should students use eLearning since they are coming on campus?' but rather 'How is eLearning contributing to the quality of their campus-based experience?' " (Piscioneri, Hlavac, & Peterson, 2010)

Secondly, the findings show that approaches incorporating e-learning are effective irrespective of the specific e-learning approach taken, the learner type, or the specific field of study. There is thus no specific 'e-learning pedagogy' required. In fact, many general learning principles, including brain compatible learning principles, that apply to learning in a classroom should also apply in an online or blended learning setting.

2.5.2 Why Brain Compatible Blended Learning?

The specific pedagogical approach followed when constructing e-learning materials for use in a blended learning environment usually matches the educational designer's pre-existing pedagogical influences instead of adhering to some 'e-learning specific theory'. For example, existing models and guidelines used by constructivists in the creation of e-learning are based on constructivist theory in general, since models and guidelines for *online* learning in a constructivist approach are still lacking (Mbati & Minnaar, 2015). The 'theory of blended learning' does not *belong* to a specific learning theory. Instead, blended learning is used as an educational method/approach within many other pedagogical approaches (Torrao & Tiirmaa-Oras, 2007).

Using e-learning aspects as part of a blended offering to enhance more traditional classroom education could thus be an important driver for pedagogical innovation irrespective of the current teaching approach. However, most lecturing staff currently believe that e-learning is about technical solutions and fail to understand that it is actually about pedagogical innovation (Salmon, 2005). Teaching with the aid of technology should be about the teaching, and *not* about the technology (Cronje, 2014).

"E-learning, whether combined with other forms of teaching and learning or not, is multifaceted and involves shifts both in understanding and behaviours. Most academics responsible for both the curriculum and the pedagogical processes arising from e-learning have not made these shifts" (Salmon, 2005). However, whilst many lecturers have not adapted to the use of technology yet, the increasing prevalence of technology has changed the behaviour and attitudes of students, including the way in which they learn and communicate (Okaz, 2015).

It has become imperative for lecturers to learn how to incorporate e-learning into their courses. Most lecturers already believe that technology use adds value to teaching and learning, but also acknowledge their own need to learn more in order to use e-learning effectively in their own courses (Mahdizadeh, Biemans, & Mulder, 2008). The application of brain-compatible principles during the design of e-learning could provide one way in which lecturers can add pedagogical rigour to their use of this medium. As mentioned at the start of this chapter, brain-compatible learning is a set of learning principles and is thus not dependent on any specific learning theory. It is for this reason that the researcher selected to investigate the effectiveness of these principles in a blended learning environment for the purpose of teaching fundamental programming logic. Therefore, the next section of this chapter briefly presents the underlying concepts that should form part of any course teaching such fundamental programming concepts.

2.6 Logical Problem Solving in Programming Education

Lunt et al. (2008) presents the most widely recognised curriculum guidelines within the field of Information Technology internationally. These guidelines, the *Information Technology 2008 Curriculum Guidelines for Undergraduate Degree Programs in Information Technology*, forms part of a series of widely recognised curricula published as a collaboration between the Association for Computing Machinery (ACM) and the IEEE Computer Society.

According to Lunt et al. (2008) programming is a core skill in Information Technology because programming concepts are used in almost all core courses. At its most basic, this skill can further be subdivided into two core modules, namely 'Fundamental Programming Constructs' and 'Algorithms and Problem Solving' (Lunt et al., 2008, pp. 32). Both of these core modules form part of the curriculum for the National Diploma: Software Development as offered by the Information Technology Department at the Nelson Mandela Metropolitan University (NMMU, 2012).

In the 'Fundamental Programming Constructs' module students are taught about various data types and structures which are used in the internal representation of data during the execution of a program. The core learning outcomes for this module predominantly relate to knowledge about how, and when to use specific structures to manipulate various types of data internally (Lunt et al., 2008, p. 103).

The second core module, "Algorithms and Problem Solving", focuses on the underlying constructs that is used to control program 'behaviour'. The learning outcomes related to this module focuses on how these *control constructs* can be used to solve problems in a logical way (Lunt et al., 2008, p. 134). The contents of this module is thus of primary importance for the purposes of this dissertation. Table 2.2 presents a list of the topics that form part of this module (Lunt et al., 2008, p. 103):

Table 2.2: Learning Outcomes: "Algorithms and Problem Solving"

#	**Learning Outcomes**
1.	Basic syntax and semantics of a higher-level language
2.	Variables, types, expressions, and assignment
3.	Conditional and iterative control structures
4.	Simple Input and Output
5.	Functions and parameter passing
6.	Structured decomposition
7.	Recursion

Each of the topics in Table 2.2 represents a program *control construct* or 'tool' that a programmer can use to help solve problems. Usually most of these constructs are used in combination with each other in order to address algorithmic problems. However, not all of these constructs are needed in every solution a programmer develops. 'Recursion', specifically, is only used in problems of a very specific, recursive, nature. Non-trivial problems of a non-recursive nature will usually require the use of a combination of all, or most, of the other constructs listed in this module.

As discussed in chapter 1; students studying towards the *National Diploma: Software Development* qualification get their first exposure to the above mentioned core areas in the subject 'Development Software 1'. This initial exposure is then reinforced in their second year by the subject 'Technical Programming 1', which specifically focusses on the reinforcement of the problem solving strategies and algorithm design skills introduced in their first year.

Since the students in 'Technical Programming 1' already studied these fundamental constructs in a previous subject, the focus during this subject is on improving the skill of the students in *applying* these concepts to construct programmed solutions to various problems. Exercises in this course thus often focus on problems that could be considered 'classical' in the field. Of specific interest to this dissertation is the use of sorting algorithms, and the use of simulations such as the 'Fizzbuzz' game, to teach programming logic.

The following subsections will briefly present an example of each of the above mentioned classical problems. These examples were also used in the construction of the e-learning based research intervention used in this study.

Sorting Algorithms

The use of computer sorting algorithms to teach programming logic is a well established feature of many algorithm courses (Kordaki, Miatidis, & Kapsampelis, 2008; Geller & Dios, 1998). These algorithms are used for many reasons, including the fact that they usually combine both fundamental data types and a wide selection of the algorithmic control constructs that is used to control the logical execution of the code.

Listing 2.1 provides the source code for the sorting algorithm that was used in the research intervention as discussed in section 3.4.2. Table 2.3 indicates the lines of code from this listing where specific structures from Table 2.2 were used. As can be seen the sorting algorithm provides extensive practice in the use of 'basic syntax and semantics of a higher-level language', 'variables, types, expressions, and assignment', and 'conditional and iterative control structures'.

```
1  bool done;
2  int value;
3  int current;
4
5  int[] NumList = { 7, 6, 9, 3, 5 };
6
7  for (int i = 0; i < NumList.Length; i++)
8  {
9  done = false;
10 value = NumList[i];
11 current = i - 1;
12 while (current >= 0 && !done)
13 {
14 if (NumList[current] > value)
15 {
16 NumList[current + 1] = NumList[current];
17 current -= 1;
18 }
19 else
20 done = true;
21 }
22 NumList[current + 1] = value;
23 }
```

Listing 2.1: Sorting Algortihm Code

Table 2.3: Algorithmic Control Structures used in Listing 2.1

#	**Line numbers where used**
1.	all 1-23
2.	1,2,3,5,9,10,11,16,17
3.	7,12,14
4.	none
5.	none
6.	none
7.	none

Fizzbuzz

The second selected example is a simulation of the children's game "Fizzbuzz". This task was chosen because it requires a clear understanding of basic decision structures in programming logic, but still requires very little time to complete. It is often used as a quick test by recruiters interviewing programmers for precisely these reasons (Atwood, 2007).

Listing 2.2 provides the source code for the fizzbuzz algorithm that was used in the research intervention as discussed in section 3.4.2. Table 2.4 indicates the lines of code from this listing where specific structures from Table 2.2 were used. As can be seen the fizzbuzz algorithm provides practice in the use of 'basic syntax and semantics of a higher-level language', 'conditional and iterative control structures', and 'simple input and output'.

```
1  for (int i = 0; i < 17; i++)
2          {
3      if (i % 3 == 0 && i % 5 == 0)
4      {
5          Console.WriteLine("FizzBuzz");
6      }
7      else if (i % 3 == 0)
8      {
9          Console.WriteLine("Fizz");
10     }
11     else if (i % 5 == 0)
12     {
13         Console.WriteLine("Buzz");
14     }
15 }
```

Listing 2.2: Fizzbuzz Algortihm Code

Table 2.4: Algorithmic Control Structures used in Listing 2.2

#	Line numbers where used
1.	all 1-15
2.	none
3.	1,3,7,11
4.	5,9,13

Continued on next page

Table 2.4 – continued from previous page

#	Line numbers where used
5.	none
6.	none
7.	none

Neither of the selected algorithms discussed above uses the ‘functions and parameter passing’, ‘structured decomposition’, or ‘recursion’ constructs. This is because the first two of these constructs usually go hand-in-hand, a student need to break a problem into smaller sub-problems (structured decomposition) before they can use individual functions (functions and parameter passing) to compute solutions to the sub-problems. The use of these constructs in relatively simple code, such as the code presented, would add unnecessary complexity. Furthermore, as mentioned before, the use of recursion is reserved for a special class of problems. The above examples were thus deemed sufficient for the purposes of the planned intervention in the ’Technical Programming 1’ subject by the researcher. However, how specific brain-compatible learning principles can be used to teach lessons based on the above identified algorithmic problem solving constructs and the identified classical problems, has not been discussed.

2.6.1 Brain Compatible Learning Principles for Programming Education

Section 2.3.2 listed and discussed various brain-compatible learning principles. The discussion in section 2.3.2 combined many of the principles that were listed in Table 2.1 and omitted others, like the principle that ‘A Healthy Lifestyle promotes Learning’ which was deemed beyond the control of a lecturer. How each of the discussed principles could be used in programming will be briefly illustrated by means of examples.

Novel patterns can only form as extensions of existing pattern

In programming education the lecturer would have to ensure that all lessons clearly link concepts back to related foundational concepts. If a student had no prior exposure to programming at all, the material would have to be related to other existing concepts that a learner already understand. For example, decision structures could be related to choices in everyday life. This principle also lends itself to the interpretation that learning of programming concepts should become easier if foundational concepts are mastered.

Short, focussed learning activities are more effective

Due to the practical nature of computer programming it should be relatively easy to intersperse short theory sessions with opportunities to write code to practice new concepts. In a classroom environment the obvious problem would be to provide individual feedback on the solutions students create to posed problems. However, some of the more advanced concepts and frameworks would not necessarily lend itself to such short, focussed activities.

There is no long term retention without rehearsal

Knowledge regarding the application of programming constructs should be rehearsed many times whenever a new concept is introduced. Such rehearsal should, as far as possible be accompanied by personalized feedback.

Emotions affect learning

Many types of computer programs are used as entertainment, and the creation of such programs can also be consider fun activities by some students. However, computers are also very good at repetitive tasks and many types of programs might be considered boring. The choice of examples and assignments would thus have to be made very carefully in order to elicit positive emotions and not ones that are detrimental towards learning.

Learning is enhanced by challenge and inhibited by threat

The creation of many forms of computer programs is naturally challenging but can also be fun. However, programming source code, by its very nature, can be also be intimidating to inexperienced learners. The syntax of many programming languages is filled with seemingly complicated symbols and obscure syntax rules. Additionally, any mistake, even a single semi-colon out of place, will result in the entire program failing completely. It would therefore be very important to construct exercises to be as non-intimidating as possible in order to avoid creating feelings of being threatened.

Learning experiences should be mulitfaceted

Programming problems can be presented in a variety of ways. Students could be asked to

- write the code to a given program design
- design the program based on a given problem
- show logic as pseudo code, or as a flowchart
- trace the working of an existing program
- debug a program to find errors.

Explanations to concepts can also be supplied in a variety of formats.

The brain processes parts and wholes simultaneously

In programming education it is a very common practice to use 'structured decomposition' to break problems into smaller sub-problems to solve. Similarly programs are designed in a modular way that allows the programmer to view the entire program in a form of 'outline' or to focus on a specific piece of code in detail.

The brain has separate implicit and explicit memory systems

As mentioned before, computer code can have very complicated syntax rules. These rules are unfortunately of a semantic nature and would thus have to be learned by rote. However, not all programming requires the use of the explicit memory system to remember. It is also possible to learn how to use many of the constructs use to teach algorithmic logic by linking to real world analogies and thus engaging episodic memory (intrinsic memory).

Learning is embedded in natural and social settings

Many approaches to programming education already leverages this principle. For example, 'pair programming' where students work in pairs at the same computer, or so-called agile software development in which requirements and solutions evolve through collaboration between self-organizing, cross-functional teams.

Each brain is unique

Programming students, just like students from most other fields, have a wide variety of backgrounds and interests. However, unlike many other fields, programming can be used in almost every other field, and in a variety of different context. It is therefore common for programming assignments to include a wide variety of types of assignments.

The search for meaning is innate

The choice of problems posed in a programming course can be instrumental in determining how relevant and meaningful a specific student might find it. Learning a specific technique through the development of a game might be very meaningful to a student interested in entertainment computing, whilst a different student might only find it meaningful if used in business context.

The search for meaning occurs through patterning

Programming education relies heavily on the ability of students to recognize new patterns and fit it into their existing knowledge of how the world works. It would be almost impossible to teach students how a computer memory works without being able to relate to existing storage mechanisms students would already know about, or to teach decision structures without relating to real world decisions that students might need to make, or iteration constructs without being able to relate to real world iterative tasks, etc. However, irrespective of the specific examples used, programming students will not grasp these concepts until they have had enough time to form the patterns internally and construct their own meaningful connections.

Learning always involves conscious and unconscious processes

Due to the complicated syntax rules of computer programming languages and the semantic nature of the learning required from students of these languages students have to consciously pay attention to specific lessons in order to gain an initial understanding of these languages. However, many of the tasks required during the practice of programming, for example tracing through the execution of source code, will also unconsciously reinforce these syntax rules. Similarly, many other opportunities for learning, both consciously and unconsciously, form part of most programming courses. However, programming lecturers might not always consciously consider the possible benefits of unconscious learning embedded in many tasks when designing learning material.

Learners need to recognize and connect patterns by themselves Many programming education approach, for example the practice of 'pair programming', lets students work in groups. However, it is vital for such pair programmers to take turns at doing the actual coding in order for them to learn. Due to the complex syntax rules, it is quite possible for students to feel intimidated to do the actual coding and therefore not wanting to actively participate. Lecturers should thus have some mechanisms in place to ensure all students get hands-on practice. Studying programming also regularly require individual students to design their own algorithms to address given problems, or to optimize given algorithms to improve efficiency.

From the above, it should be clear that all of the brain compatible principles that was discussed in detail earlier in this chapter would also be appropriate for use in programming education.

2.7 Summary

This chapter introduced the field of brain-compatible learning as a theoretical basis for the research in this dissertation. The chapter briefly discussed how the brain learns from a biological perspective and then introduce various brain-compatible learning principles from the literature. The chapter also discussed the concept of blended learning and briefly elaborated on the reasons for using such a blended learning approach as an intervention. Finally the chapter discussed the purpose of logical problem solving in programming education before providing examples of how identified brain-compatible learning principles *could* be used in programming education in section 2.6.1. The presentation of these principles in section 2.6.1 answers the first secondary research question posed in section 1.4 of this study, namely; *'Which brain-compatible learning principles could be used in the explanation of subject material dealing with algorithms and problem solving?'*

Chapter 3

Methodology and Research Design

3.1 Introduction

This chapter introduces the researcher's paradigmatic stance, the research process that was followed and the methodology used in this study. The chapter also discuss the design of the research intervention used in this study, how the experiment itself was conducted and the design of the data gathering instruments used in the study.

3.2 Paradigmatic Stance

All research is influenced by the researcher's underlying philosophical assumptions. This holds true irrespective of whether the researcher is aware of his/her own underlying assumptions or not (Collis & Hussey, 2003). Such assumptions form a part of the researcher's personal ontological world view and will influence everything the researcher does, including his/her choice of a research paradigm and research methodology. Collis and Hussey (2003) provides a continuum of possible core ontological assumptions, as shown in Figure 3.1, that could stem from a researcher's philosophical stance.

This continuum ranges from the quantitative to the qualitative. Researchers who primarily do quantitative, or positivistic, work usually have a corresponding philosophical view that reality is a concrete structure. This philosophical view also leads to the underlying assumption that is possible to

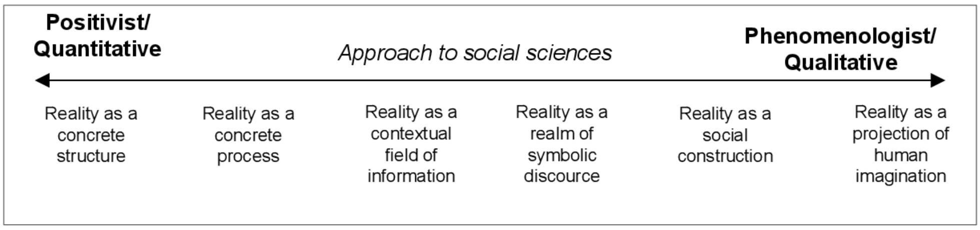

Figure 3.1: Continuum of core ontological assumptions (from (Collis & Hussey, 2003, p. 51))

measure and interpret this single reality objectively. Conversely, researchers on the qualitative, or interpretive, side of the continuum base their work on the underlying philosophy that reality is experienced, and interpreted, differently by different humans. Reality is thus seen as an extension of each person's imagination. Such qualitative researchers view it as important to acknowledge the subjective nature of the human being doing the research, and to disclose this person's ontological biases, where possible, since these biases will influence how such researchers interpret their research. Qualitative work therefore focus more on the *interpretation* of the research than on the exact *measurement* of results (Collis & Hussey, 2003, p. 53).

Even though it is widely accepted that qualitative research can help information systems researchers to understand human thought and action in both social and organizational context (Klein & Myers, 1999), researchers studying such phenomena in an organizational context might still choose to not use such methods if they clash with their own research philosophy.

The following five categories of philosophical assumptions can lead to an individual's choice to do qualitative work (Creswell, 2007, pp. 16-19), (Ritchie & Lewis, 2003, pp. 11-23):

1. Ontological: The researcher believes in 'multiple realities'. In other words, the researcher believes that even supposedly objective studies are still influenced by the person doing these studies' subjective interpretation of the results. There can thus be more than one interpretation of the same reality. Research subjects being interviewed might also experience the same reality in different ways.

2. Epistemological: The researcher believes that getting as close as possible to the subjects being studied will result in a 'better' study.

3. Axiological: The researcher tries to make his/her 'values' explicit. In other words, the researcher admits to being subjective, and tries to "actively report their own values and biases as well as the value-laden nature of the information gathered from the field" (Creswell, 2007, p. 18).

4. Rhetorical: Qualitative researchers tend to write in a more personal and literary form. They might employ terms such as 'credibility' instead of 'objectivity'. The language used in the study is often based on definitions that evolved during the study, as opposed to definitions the researcher him/her self brought to the study.

5. Methodological: Qualitative researchers use inductive logic, as opposed to the deductive logic used by quantitative researchers. They usually study the topic within its context, and continually revise questions based on experience gained.

The above philosophical assumptions might lead to a researcher doing qualitative work. As mentioned earlier many research works make no clear distinction between 'qualitative' and 'interpretive' work (Klein & Myers, 1999). However, these terms are not synonymous; **qualitative work may or may not be interpretive** and will generally fall into one, or more, of the following four main research paradigms (Creswell, 2007, pp. 19-23)

1. Post-positivism - This is mainly a scientific approach and the researcher will likely view inquiry as a series of logically related steps. These researchers believe that reality exists, but that it can only be known imperfectly (Robson, 2002). This research usually espouses rigorous methods of data collection and analysis. Post-positivst approaches strongly resemble quantitative approaches.

2. Constructivism (**Interpretivism**) - In this form of research, subjective meanings are formed through interaction with others. "Rather than starting with a theory (as in post-positivism) inquirers generate or inductively develop a theory or pattern of meaning" (Creswell, 2007, p. 21). These researchers often address processes of interaction among individuals. The findings of these researchers are 'shaped' by their own interpretations.

3. Advocacy/Participatory - This type of research contains an action agenda that might change the lives of participants. Action research as a methodology is probably the best known example of work in this paradigm.

4. Pragmatism - Pragmatism focuses on the **outcomes** of the research more than the antecedent conditions. In other words, in pragmatism the application(s) of the research is more important than focusing on rigorous methods. In practice, the researcher will often employ multiple methods to best answer the research question (Creswell, 2007, p. 23).

From the above paradigms and philosophies it should also be clear that qualitative methods are not always easy to classify. However, it should be clear that "the criterion of confirmation through data should be played down relative to what books on method normally suggest, and conceptions of the nature of empirical material should be changed as compared to traditional epistemology" (Alvesson & Sköldberg, 2000, pp. 275-276). That does not imply that empirical material is unimportant. But it should be consigned a considerably less clear-cut and robust character. Empirical data is still "*an expression on negotiable, perspective-dependent interpretations*" and is conveyed in an ambiguous language. "*Empirical material should be seen as an argument in efforts to make a case for a particular way of understanding social reality...*" (Alvesson & Sköldberg, 2000, pp. 275-276).

The above philosophies and paradigms can lead to many distinct approaches towards qualitative studies. Some of these methodologies have strong empirical grounding, e.g. post-positivist, while others might be more interpretive. It is even possible for one methodology to borrow from more than just one of the qualitative paradigms. This wide array of choices available to qualitative researchers not only makes it difficult for the researcher him/her self to choose a specific philosophy, ontological stance and methodology, but also makes it very difficult for future researchers who want to build on such a researcher's work to judge the compatibility of published work with their own philosophies and methods.
To fully evaluate the applicability of another researcher's work to his/her own work, a researcher must be able to understand the philosophical choices made by that prior researcher. This is especially true in qualitative work, which is

inherently biased. Without insight into the prior researcher's possible biases a future researcher might be unable to ascertain the applicability of the prior work as a basis to his/her own work. It is thus essential for a researcher to declare his/her own philosophical bias and paradigmatic stance.

Saunders et al. (2007) provide a layered approach towards explaining research choices known as the 'research onion'. This is a popular way (and perhaps one of the easiest) to understand, and present, the plethora of choices a researcher has to make. Figure 3.2 depicts this research onion.

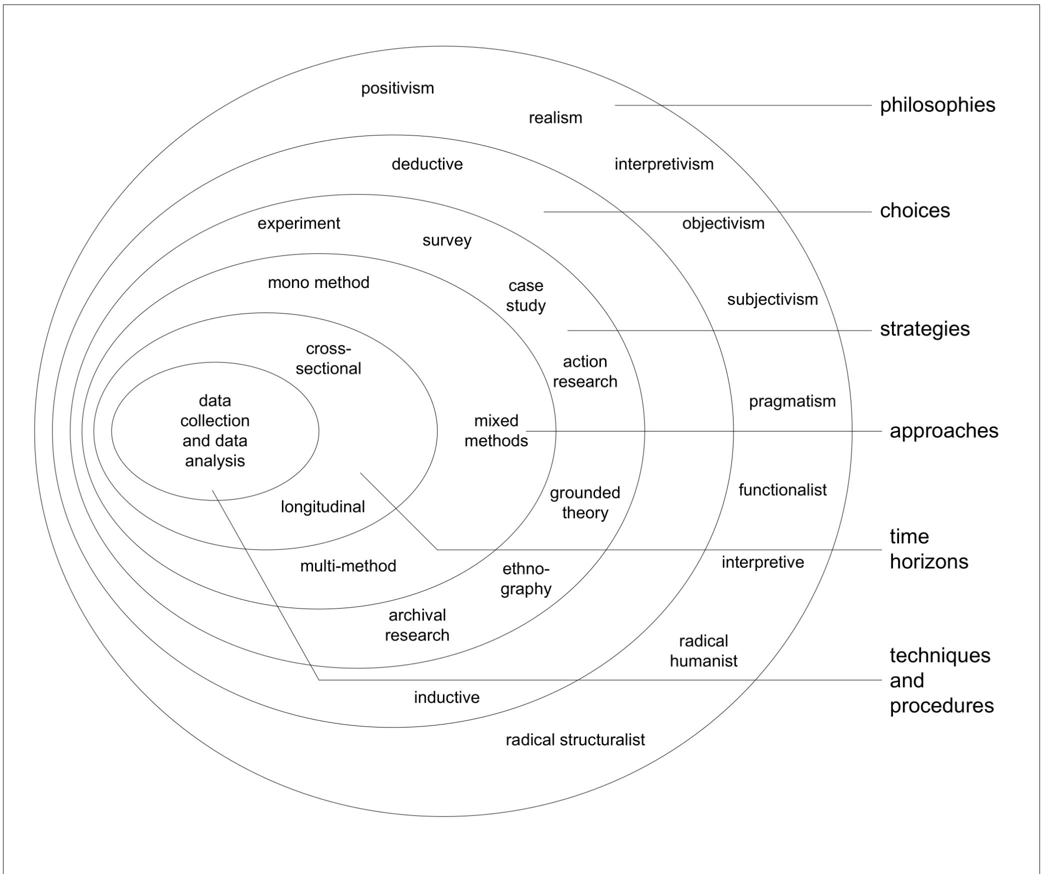

Figure 3.2: Research Onion. Adapted from (Saunders et al., 2007)

When using the research onion the research would start at the outer layers and proceed inwards in the espousing of their research choices. At the first layer lies the philosophical stance of the researcher. To a certain extent, the choice of philosophy will determine whether the researcher's work will be primarily deductive (in which a theory and hypodissertation is developed), or inductive (in which data is collected and a theory developed as a result of the data analysis). This choice will in turn lead to the choice of research strategy which could include case studies, action research, surveys, etc. Research strategy choices lead to an overall research approach, including mono method, multi-method, or mixed-method approaches. The research approach helps to determine the time horizons of the research (longitudinal or cross-sectional), which in turn leads to specific techniques and procedures (including focus group research, interviewing, questionnaires, etc). It is not the researcher's intention to recommend the use of the research onion as *the solution* to the discussed problem of determining the quality/validity of qualitative work. The use of a construct *similar to this research onion*, as a form of checklist, could ensure that the necessary information is available to allow the reader to make an informed judgement of the validity and/or applicability of the research to his/her own research needs. Such a list does not necessarily have to include all aspects outlined by the research onion. Instead **it should only list all aspects which are *applicable* to the specific study**. The following list serves to espouse the philosophical choices made for this dissertation, in terms of the general framework provided by the research onion:

- Philosophy: The work in this dissertation was conducted based on a **pragmatic** philosophy. The researcher does not prescribe to either a strict positivist, or a strict interpretive viewpoint. Instead, the researcher believes that methods should be chosen based on their *suitability for the specific task at hand.*

- Choices: The work in this dissertation is primarily of an **inductive** nature. Research questions were posed and data was then gathered by means of an experiment, and analysed in order to answer the posed research questions.

- Strategies: The primary research strategy was to conduct a research **experiment** in the form of a teaching intervention. The intervention used in the **experiment** was constructed following a **design science** approach. The guidelines for the use of **design science**, as presented by Hevner, March, Park, and Ram (2004), are discussed in more depth in section 3.4. This strategy was extensively supported by **evidential and narrative argumentation**.

- Approaches: A **mixed method approach** consisting of both qualitative and quantitative methods was used.

- Techniques and Procedures: The research methods, techniques, and procedures used for specific elements of this study are espoused in the discussion below.

3.3 Research Process

The primary purpose of this research was to investigate the effectiveness of brain-compatible blended learning material in the teaching of programming logic. This research stemmed from a desire to address an observed problem in the subject Technical Programming 1, which forms part of the foundational education of software development students in the School of Information and Communication Technology (ICT) at the Nelson Mandela Metropolitan University. This subject had a very high failure rate which, in the researchers opinion, could be partially ascribed to the large number of students in a typical class for this subject. The researcher believed that the use of brain compatible blended learning material to augment the lectures in this subject might have a positive effect on student learning. This study was conducted in order to test this premise.

The researcher performed three literature studies during the initial phases of this research. The first literature study aimed to determine what *brain compatible* education is, and what principles an educational intervention would have to adhere to in order to be considered *brain compatible*. A second literature study was conducted to determine what *blended learning* is. Finally, a literature study was conducted in the field of programming education. The aim of this third literature study was to identify a set of fundamental programming logic skills (learning objectives) that would be appropriate as a basis for this study. Based on the results of the literature studies the researcher created an educational intervention which incorporated *brain compatible learning* principles into a *blended learning* medium. An instrument to measure the effect that using this intervention would have on student motivation to learn was then developed by adapting an existing instrument to the specific needs of this research study. In addition, a second instrument in the form of an assessment exercise to measure the participants' fundamental programming logic skills was created by the researcher. The intervention was then tested experimentally.

Firstly, permission to conduct the experiment to test the effect of the educational intervention was gained from the institutional research ethics committee, the management of the School of ICT, and the lecturer responsible for the subjects. Students from the Technical Programming 1 subject were recruited for participation in this experiment. The experiment was then conducted in accordance to all requisite ethical guidelines. The experiment took place during the subject's normal practical sessions over a two week period. Figure 3.3 show the basic steps followed during this experimental process. The participating students were sub-divided into an experimental group and a control group (see section 3.4.1) but did not know which of these groups they belonged to. After initial division into these groups some of the students were allowed to swap places with other students in a different group in order to accommodate their individual needs. Students had the option to not participate in the experiment at all and several students exercised this option.

During the first practical session the control group was given specific concepts to study and tasks to complete in a format that was consistent with the usual way in which material was presented in this course. This practical session was only attended by control group students. The material was made available in a blended learning medium, but did not adhere to the identified brain compatible learning principles. Thus, whilst the experimental group's work adhered to all the principles discussed in section 3.4.3 this control group's practical was not broken into several smaller tasks, did not use animation and colour, had no automated feedback, did not present the flow of the logical in several ways to make use of focussed and peripheral attention, and did not repeat the same work several times in different formats.

During the second week the experimental group was given tasks based on the same concepts as the control group, but in a brain compatible format. These tasks thus covered the same fundamental programming concepts as those assigned to the control group. However the tasks were designed to engage the students according to selected brain compatible principles.

After both groups completed their assigned practical exercises the students wrote a non-summative class test, in the form of the designed instrument, which evaluated their understanding of the concepts covered by work during the experiment. Subsequent to the intervention the students were

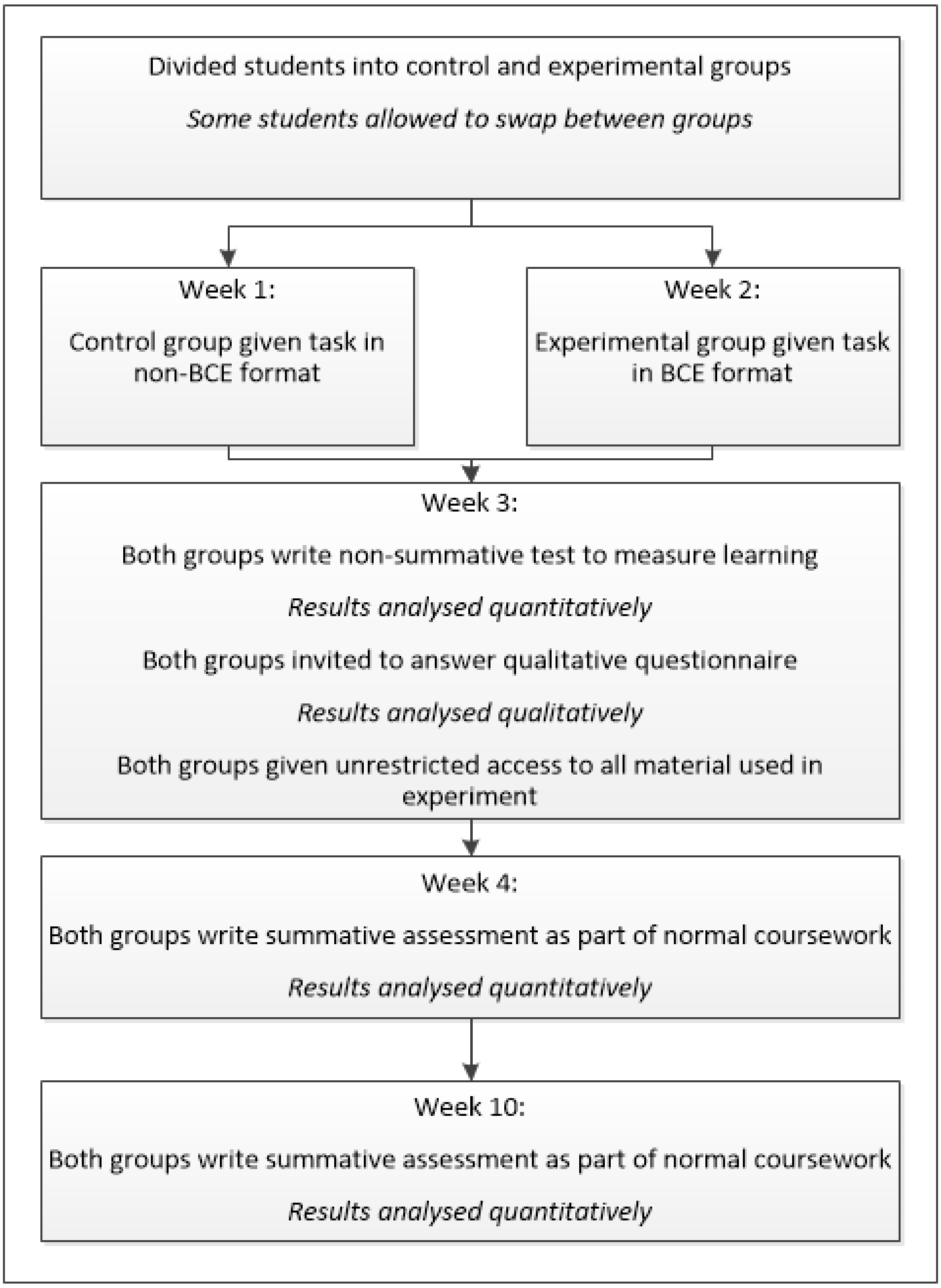

Figure 3.3: Experiment Process Flow

asked to complete the questionnaire that was adapted to measure motivation to learn (see section 3.4.5). After the completion of the experiment all students, including both the control group and those who elected to not participate in the experiment at all, were given unlimited access to the online brain compatible material. This concluded the experimental phase of this research. However, in order to answer the research question *What effect will* *the use of brain-compatible e-learning material have on the student achievement?*, as posed in section 1.4, the researcher subsequently also analysed the performance of the participants in the subject's formal semester tests. It should be noted that these semester tests did not form part of the experiment and was set, administered, and graded, by the subject's lecturer with no prior knowledge regarding the specific material that was covered in the experiment.

The research found quantitatively that intervention had a positive effect on learning that was of moderate practical significance. Qualitatively the research showed that the students had a generally positive view of the approach used in the intervention. These results are discussed in detail in subsequent sections.

3.4 Methodology

As mentioned earlier, the work in this dissertation was conducted based on a pragmatic philosophy. The researcher does not prescribe to either a strict positivist, or a strict interpretive viewpoint. Instead, he believes that methods should be chosen based on their suitability for the specific task at hand (Creswell, 2007). The various elements comprising the research intervention itself was developed using a *design science* approach and the researcher adhered to all the guidelines for this research strategy, as presented by Hevner et al. (2004). The design science paradigm was chosen over a traditional instructional design approach because the developed intervention was in the form of an IT based artifact and the development process matches the design science approach exceptionally well.

According to Hevner et al. (2004) design science is "fundamentally a problem solving paradigm". The approach is often used in research focusing on systems design in the field of Information Systems and was therefore selected as an appropriate method for the design of the technology based research intervention used in this study. Hevner et al. (2004) provides seven guidelines that a design process should adhere to in order to meet the requirements for design science research. The following outline explains how the design process followed to create the research intervention for this study adheres to the guidelines provided by Hevner et al. (2004):

- **Guideline 1: Design as an Artifact**. According to Hevner et al. (2004) design science research must result in a design artifact. One of the examples for such an artifact provided by Hevner et al. (2004) is a 'purposeful IT artifact' created to address an important problem. This research used design science to create such an IT artifact in the form of a technology based intervention with the purpose of teaching specific aspects of fundamental programming logic.

- **Guideline 2: Problem Relevance**. The second criteria stated by Hevner et al. (2004) is that the problem the artifact seeks to address should be considered important and relevant. The relevance of this research intervention was argued in chapter 1.

- **Guideline 3: Design Evaluation**. Hevner et al. (2004) states that the utility, quality, and efficacy of the design must be demonstrated rigorously. The appropriateness of the design of this intervention is firstly argued below, based on methods as discussed in Mason (1996, pp. 187-189). The efficacy and the utility of the design is illustrated by the research results presented in this dissertation.

- **Guideline 4: Research Contributions**. "Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies" (Hevner et al., 2004). The primary contribution of this design is to demonstrate how brain-compatible education principles can be implemented in an e-learning environment in order to teach some aspects of fundamental programming logic.

- **Guideline 5: Research Rigour**. Strict adherence to the guidelines provided by Hevner et al. (2004) ensured the research rigor of the design process. The specific design decisions made are also extensively argued and were derived from the theoretical foundation provided by the literature study done in this dissertation.

- **Guideline 6: Design as a Search Process**. The process through which the intervention was designed occurred over an extended period of time (12 months). Firstly various brain-compatible learning principles were identified as suitable to include in the intervention based on literature work. Various approaches towards using the identified principles was then implemented, tested, and evaluated by the researcher for suitability. The final intervention was thus the result of a rigorous process consisting of several iterations.

- **Guideline 7: Communication of Research**. A paper based on this research was prepared and submitted to the journal 'Computers and Education'. However, this paper is still in the process of review. This dissertation itself also serves as communication of the design, satisfying the criteria for communicating the research.

Both qualitative and quantitative data generating instruments were used. More detail regarding these, and other methodological considerations, are supplied in subsequent subsections.

3.4.1 Sample and Setting

This study was conducted within the Information Technology department of the School of ICT at the Nelson Mandela Metropolitan University. The participants for the study was specifically selected from the Technical Programming 1 (PRT1000) subject that forms part of the National Diploma: Software Development qualification. The sample used was both *convenient* and *purposive*. A convenience sample is a sample that is "available to the researcher by means of its accessibility" (Bryman, 2012, p. 201).The Technical Programming 1 class was *convenient* to the researcher because the researcher is a staff member within the same department at the School of ICT and thus had easy access to this class. Secondly, the researcher used a *purposive* sampling approach where participants were specifically selected "so that those sampled are relevant to the research questions that are being posed" (Bryman, 2012, p. 418).

The researcher lectured this specific subject in the past and was thus intimately familiar with the subject material, and the specific problems students within this subject might experience. Because the researcher no longer personally lectured the subject it meant that he would not influence the results unwittingly. As discussed in section 1.1 this subject focusses on fundamental algorithmic problem solving skills for software development students. However, despite the first year level of the subject content, the students in the

Technical Programming 1 class are second year students who have already passed the subject Development Software I, which is a prerequisite subject to Technical Programming 1. These students are thus already familiar with basic programming syntax. This made it easier for the researcher to focus on the underlying concepts specifically related to fundamental programming *logic*.

Lectures for the Technical Programming 1 subject consists of both theoretical and practical sessions. Practical sessions are conducted in a computer laboratory and consisted of three consecutive lecturing periods of 45 minutes each. The research experiment took the form of an intervention during two of these practical sessions in August 2013. For this experiment the participating students were sub-divided into both an experimental and a control group. At the time the experiment was conducted students in the Technical Programming 1 class already wrote two semester tests for the subject. The researcher used the results of these earlier semester tests to ensure that the experimental and control groups were as balanced as possible. These groups were created as follows:

1. A year-to-date average mark was calculated for each student based on the average mark the student received for the two prior semester tests (major summative assessments).

2. The class list for the subject was sorted in ascending order of the above year-to-date mark.

3. Alternating students from this class list sorted according to year-to-date marks were allocated to the experimental group, the remainder to the control group.

Students were not informed whether they were allocated to the control group or the experimental group. instead they were allocated a specific practical session to attend. Students attending the first of the two practical sessions(12 August 2013) were used as the control group (N = 68). Subsequently, attendees of the second practical session (19 August 2013) were used as the experimental group (N = 46). It should be noted that, in compliance with research ethics constraints, student participation in the research was completely voluntary and students were allowed to choose not to participate during any stage of the research. Several students chose not to participate, especially during the second session, which resulted in the uneven number of students in each of these groups. No data from students who chose to exercise their right to not participate were included in either the experimental or control group data. However, as will be shown during the analyses of the data, these uneven numbers of participants had no measurable effect on the data. It is also important to note that all students in this subject were already used to working in a blended learning environment and that 'normal' material for the course includes material in an e-learning format. The positive effects of using e-learning in a blended environment, as discussed in section 2.5.1, would thus not skew the results of this research. Any positive results should thus be attributable to the brain-compatible nature of the intervention.

3.4.2 Intervention

As mentioned before, the intention of this research was to determine whether the use of brain-compatible material in an e-learning format would have a beneficial effect on student learning in the subject Technical Programming 1. In order to test this an intervention was designed based on two tasks that the researcher considered to be appropriate for students in this subject. The first task selected was to write the code for a given computer sorting algorithm. The use of computer sorting algorithms to teach programming logic is a well established feature of many algorithm courses (Geller & Dios, 1998; Kordaki et al., 2008). This was thus considered an ideal task for this intervention. The second task selected was to write a program to simulate the children's game "Fizzbuzz". This task was chosen because it requires a clear understanding of basic decision structures in programming logic, but still requires very little time to complete. It is often used as a quick test by recruiters interviewing programmers for precisely these reasons (Atwood, 2007).

Control Group Intervention

A practical exercise based on the above tasks were created for students in the control group of this experiment. For both of these tasks the students were provided with a step-by-step description of the required algorithm and then

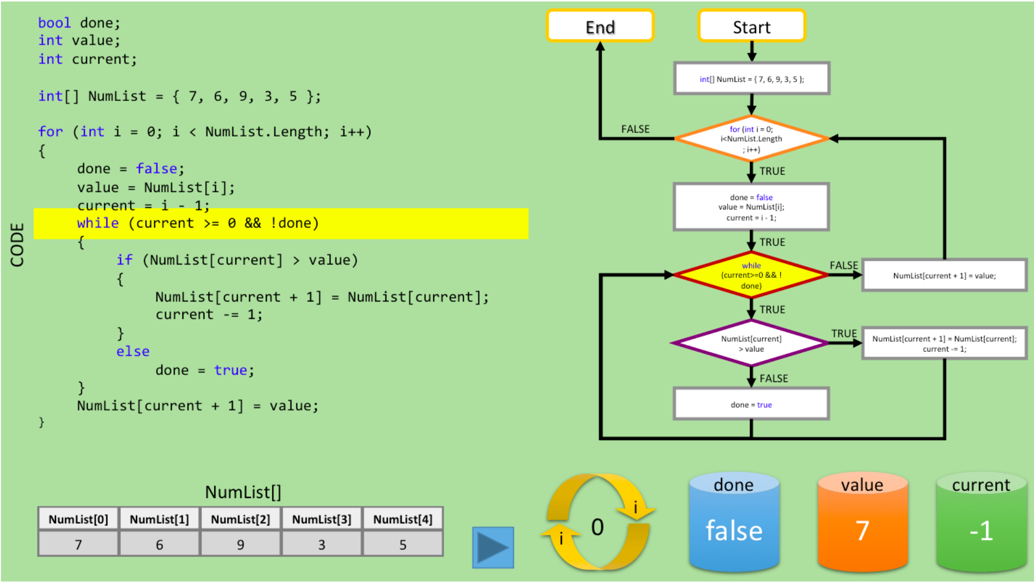

Figure 3.4: Interactive sorting algorithm presentation

had to write their own code implementation for each algorithm. Students were also given links to appropriate wikipedia content that might be of help should they require further clarification. This format is typical for *normal* practical exercises in this course.

Experimental Group Intervention

For the experimental group a variety of material was created that adhered to previously identified criteria for brain-compatible e-learning material. A full discussion of the prinicples used, and how the elements discussed in this section adheres to these principles, is supplied in the next sub-section. Firstly, an interactive powerpoint presentation was created for each task. Each presentation firstly explained the purpose of the specific task, and then provided the student with both the source code that would solve the problem, and a schematic presentation of the programming logic used. Further representations were given displaying the current value of all relevant variables defined in the code that were currently in scope for the problem, as well as a trace table showing the prior value of all variables. Figure 3.4 presents a screen shot from the sorting algorithm presentation. The student then had to step through the code a statement at a time whilst observing the value changes caused by each line of code. As can be seen in Figure 3.4, the current line of

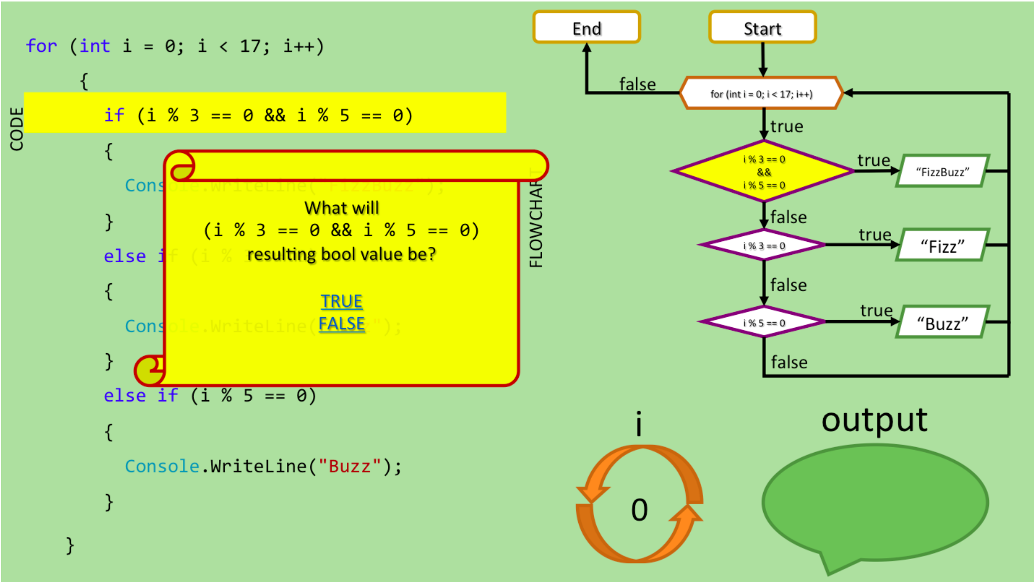

Figure 3.5: Interactive question during fizzbuzz code execution

code to be executed is highlighted in yellow during this step-through mode. The interactive presentation would occasionally require the student to answer a question about the expected effects of the current line of code. Such a question for the fizzbuzz task is shown in Figure 3.5. Based on the answer to the questions posed, the student would receive immediate positive or negative feedback, as well as an explanation as to why the answer was deemed correct, or incorrect. Figure 3.6 shows such immediate feedback during the fizzbuzz task. It is important to note that no marks were allocated for answers to these questions in order to keep this part of the intervention non-threatening.

Secondly, in addition to the interactive presentations for each of the tasks, a third presentation was made explaning in detail how the concept of a modulus (remainder) to test whether or not one number is divisible by another is used in the fizzbuzz code. Thirdly, two narrated (audio) explanations was created, each consisting of a pencast video in pdf format. These pencasts was recorded using a livescribe electronic pen and presents the viewer with a discussion consisting of both handwriting and recorded audio wherein the researcher firstly explains and discusses the concept of one number being a divisor of another, and then how this is used in the fizzbuzz task and what the common pitfalls is to watch out for in this task.

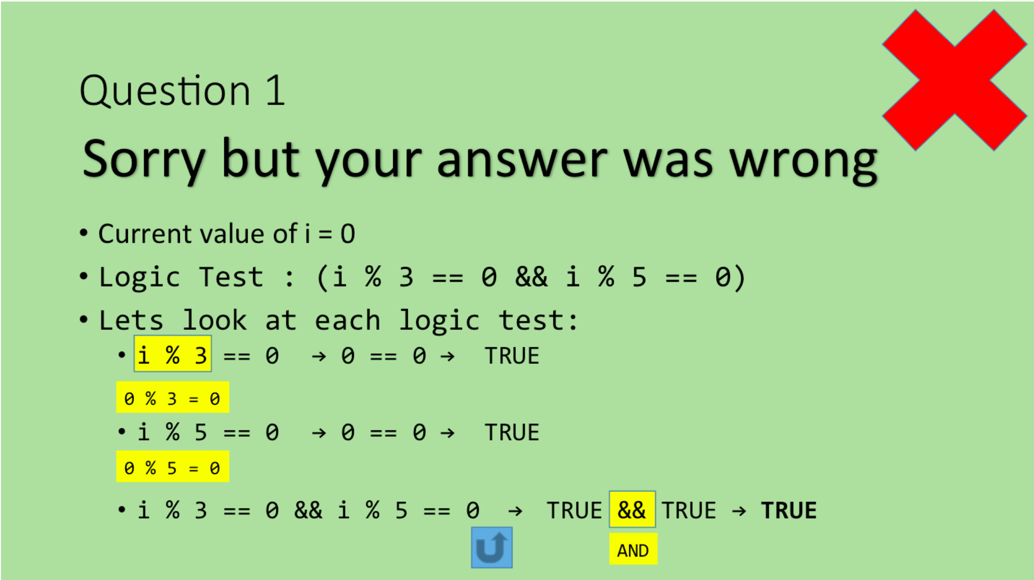

Figure 3.6: Example of immediate interactive feedback during fizzbuzz task

Fourthly, an interactive discussion of the sorting algorithm was created in the form of a moodle lesson. This lesson used the same colour scheme as the power point presentations but required more student input and had an associated formative assessment mark allocated for each question asked. Figure 3.7 shows an example question from this moodle lesson.

Finally, a short summative quiz consisting of three questions that each requires the student to once again apply the studied underlying principles was created. This added the need to once again perform the task, this time under the stress of what he/she believes to be a summative assessment.

3.4.3 Brain compatible principles used in intervention

Collectively the above elements provided an intervention that adhered to several brain-compatible principles:

- The intervention consists of several small tasks, each of which takes between 5 and 10 minutes to complete. Jensen (2008, pp. 29) recommends limiting cognitive activities to periods of 5 to 10 minutes each. This is because "learning is best when focused, diffused, and then focused again" (Jensen, 2008, pp. 28).

- Animation and colour changes were used to highlight currently exe-

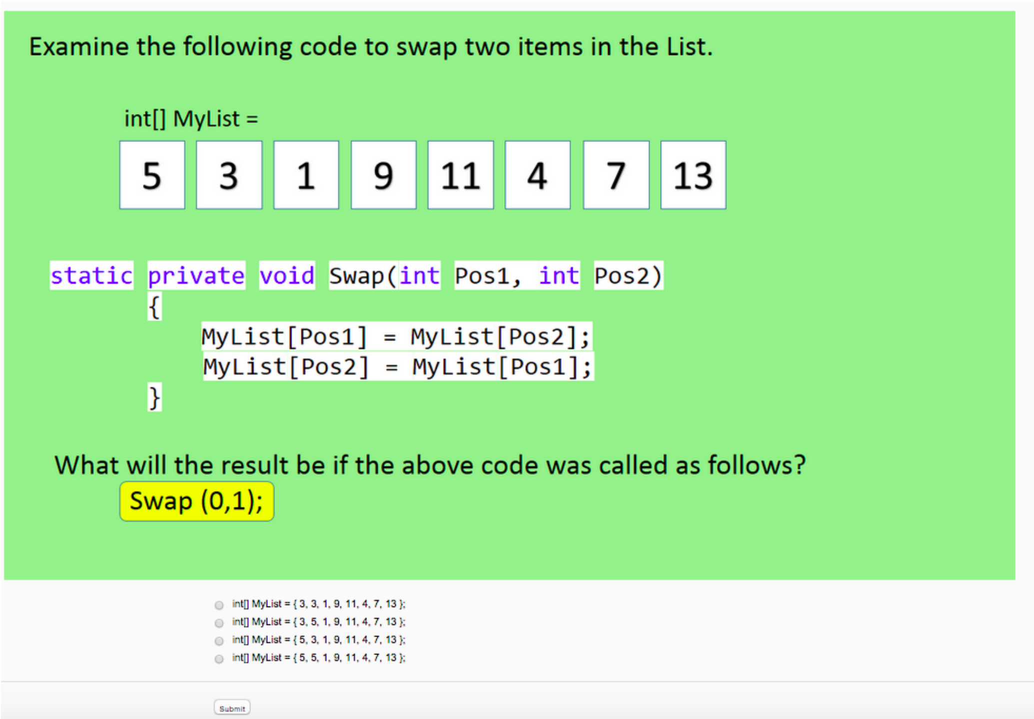

Figure 3.7: Example question from moodle lesson

cuting lines of code and to draw the student's attention to important features. According to (Jensen, 2008, pp. 55) one should "attract the brain with movement, contrast, and color changes. Our visual system is designed to play close attention to those elements because they each have the potential to signal danger."

- Colours chosen were included the use of yellow to highlight the currently executing code, because yellow is the first colour the brain distinguishes, and green as a background colour, because green encourages productivity (Taylor, 2008; Bradshaw, 2003).

- Several forms of feedback is used to encourage learning. Firstly the learner receives feedback after answering the questions included in the moodle quiz and lesson. Secondly, the interactive presentation provides continuous visual feedback in the form of changing values of internal code variables during the simulated walk-throughs. Lastly the presentation also provide detailed instantaneous feedback to the answers provided to questions during the interactive simulations. According to Jensen (2008, pp. 195) "the best feedback is immediate, positive, and dramatic".

- "Learning involves both focused attention and peripheral perception" (Fogarty, 2009). Thus, even whilst attention is focused on a specific task the brain is aware of other peripheral sensory (visual, kinaesthetics, etc.) inputs (Fogarty, 2009). The interventions firstly supplied additional sensory inputs in the form of visual representations during the simulated tracing of source code. Thus, whilst concentrating on the code, the student's peripheral attention would note that variable values change according to the logic dictated by the code statements. Secondly, the algorithms were also modelled in the form of logical flowcharts using symbols that is commonly used in programming education to represent the execution of various control structures (Farrell, 2002). These flowcharts were also animated through highlighting the currently executing code. Finally, the narrated discussions provided both written illustrations of concepts and narrative audio explanations.

- The brain processes parts and the whole simultaneously (Fogarty, 2009). According to (Banikowski, 1999) people learn "by organizing new information into hierarchies and organizing information so that the relationships between isolated bits of information can be detected". The simulations were thus designed so that the learner could perceive the entire algorithm in the form of both code and the provided flow diagram, whilst simultaneously highlighting the sub-part currently in context. Insight into the underlying values of variables were also given both for the whole and the currently executing code. This also engages both visual and verbal faculties which encourages meaningful learning (Lombardi, 2008).

- It is important to provide both multiple opportunities and sufficient time to allow learners to grow knowledge structures through sufficient, specific practising and processing of any newly learnt or modified concepts (Smilkstein, 2003, pp. 128). Repetition of newly learned concepts is extremely important to prevent the "pruning" or removal of newly grown synaptic connections in the brain that might be deemed unneeded (Lopez & Alipoon, 2001). All activities in the intervention thus repeat the same underlying fundamental programming logic concepts, namely, decision structures that compare two choices and for each choice choose a specific action based on underlying data values, and looping structures that controls code iteration through a predetermined list of values.

It is important to note that the brain-compatible intervention still had the exact same underlying tasks as the normal practical exercise that the control group had to complete. The tasks were simply structured into a more brain compatible format.

3.4.4 Data Generating Instruments

As mentioned earlier, this research used both qualitative and quantitative data. A qualitative questionnaire was completed by the students after completion of the experiment. This instrument was derived from one previously used by Du Plessis (2010) and were used to measure student motivation to use the brain compatible material. The questions in this instrument are organized into several broader themes. Table 3.1 presents the broad thematic questions and how they relate to specific underlying questions of this instrument.

Table 3.1: Broad thematic organization of qualitative data gathering instrument

Questions	**Type**
Theme 1: Similarilty of e-learning content to 'normal' classes	
Q 1. Is learning the e-learning content different than the learning in your normal class?	Yes/No
Q 21. The e-learning module lessons are similar to other lessons in class.	Likert scale
Q 26. The lessons you have in class are more or less the same as the e-learning lessons.	Likert scale
Q 33. The e-learning lessons are similar to other subject lessons you have done before.	Likert scale
Theme 2: E-learning content is engaging (enjoyable)	
Q 2. Do you enjoy the type of learning used in the e-learning module?	Yes/No

Continued on next page

Table 3.1 – continued from previous page

Questions	**Type**
Q 6. The e-learning material was engaging.	Likert scale
Q 15. Do you think other learners would enjoy this type of learning activity for other subject material?	Yes/No
Q 17. You enjoyed working on the e-learning module lessons.	Likert scale
Q 18. Do you enjoy the e-learning lesson format as way of learning about a subject?	Yes/No
Q 20. Could you see yourself working on other subjects using the e-learning lesson presentation method?	Yes/No
Q 25. The e-learning lessons are boring and do not catch your interest.	Likert scale
Q 27. You often think about other things not related to the subject when you are busy with a e-learning lesson or media resource.	Likert scale
Q 28. You feel positive about your e-learning experience.	Likert scale
Q 29. You enjoy the e-learning experience.	Likert scale
Q 35. Other learners would enjoy the e-learning presentation formats as a teaching and learning strategy for other subjects.	Likert scale
Q 36. You enjoy the e-learning lessons as a teaching and learning strategy to introduce the programming and logic topics.	Yes/No
Theme 3: E-learning content is preferred	
Q 3. Do you enjoy this type of e-learning more than your normal class?	Yes/No
Q 4. What learning approach would you prefer?	E-learning/ Normal/ Both
Q 16. Did the e-learning module lessons and resources help you learn in an interesting way?	Likert scale
Q 30. Doing the e-learning modules sure beats listening in class.	Likert scale
Q 31. You would prefer to work on the subject matter in a format which is not an e-learning method.	Likert scale
Q 32. You would prefer to do the subject matter using the e-learning approach rather than using other learning methods.	Likert scale
Theme 4: E-learning content created a positive learning environment	
Q 5. The e-learning module allows you to work at a pace suitable to you.	Likert scale
Q 7. The feedback provided in the e-learning content improved your learning experience.	Likert scale
Q 8. You could relate to the examples provided in the e-learning module	Likert scale

Continued on next page

Table 3.1 – continued from previous page

Questions	Type
Q 10. The background colour of the module lessons was encouraging.	Likert scale
Q 11. The material was easy to navigate through.	Likert scale
Q 28. You feel positive about your e-learning experience.	Likert scale
Theme 5: Material was 'rich' enough (multimedia)	
Q 9. The amount of animations used in the e-learning content kept you interested in the course material.	Likert scale
Q 12. Fewer animations in the e-learning module lessons would have been preferable.	Likert scale
Q 13. Having multiple resources (e.g lessons and other media) for each concept taught aided your understanding of the concept being taught.	Likert scale
Q 14. The use of animations in the lessons helped explain the related lesson concepts	Likert scale
Theme 6: Student feels that they have *learned*	
Q 19. When you have learnt and completed a e-learning module, do you feel like you have gained knowledge which is yours?	Yes/No
Q 22. You learn lots of new things during the completion of the e-learning modules.	Likert scale
Q 23. You know and remember more about each module topic after completing each module's e-learning lesson.	Likert scale
Q 24. You learn more about the programming topics when you complete a e-learning lesson than what you learn with other learning methods.	Likert scale
Q 34. You find the benefits of the e-learning modules (lessons and resources) to be valuable to your learning experience.	Likert scale
Q 37. Do you think this e-learning course's material and presentation has benefited you in any way?	Yes/No
Theme 7: Open ended questions	
Q 38. What did you like about the e-learning material?	Open ended
Q 39. What did you NOT like about the e-learning material?	Open ended
Q 40. Are there any additional comments you wish to add about the material, its presentation and its content?	Open ended

A copy of this questionnaire can be found as Appendix A of this dissertation. It is important to note that the primary purpose of this instrument was to measure how well the e-learning intervention engaged the students.

This instrument was designed early in the study due to administrative requirements linked to the need to obtain ethical approval for the project and it was thus not feasible to revise it to be more specific to the final version of the intervention itself, which was only available later on. This is a weakness in the current study which should be avoided in future work of the same kind.

To generate quantitative data two approaches were followed. Firstly, this research made use of the standard summative assessments, known as semester tests, used in the subject. The subject is a year course and have four such semester tests during the course of the year. As mentioned before, the researcher had no involvement in either the setting of these assessments or the grading of these assessments. The subject's lecturer, who set and graded the assessments, also had no involvement in the research experiment. Secondly, the researcher created an additional assessment that was specifically intended to measure the immediate effect of the intervention. This assessment was administered to students of both the experimental group and the control group one week after the intervention. The additional assessment consisted of the following three questions:

1. Write a function called SumOfDiv(int N) that will take in a number (N) and return the **sum** of all the **divisors** of that number that is **smaller than the number itself**.

2. A number N is considered ***perfect*** if that number is equal to the sum of all the divisors of N that is smaller than N itself.

   For example:

   The divisors of 6 is 1, 2, and 3. Because 6 = 1 + 2 + 3 we can say that 6 is *perfect*.

   The divisors of 8 is 1, 2, and 4. Because 8 != 1 + 2 + 4 we can say that 8 is **not** perfect.

   Write a function called bool IsPerfect(int N) that will return true if and only if the number N is a perfect number. (NOTE: You may call the function in Question 1 to do some of the work for you.)

3. Write a program that will check each number (starting from the number 2) until it has found the first 5 perfect numbers that exist. Each time

a perfect number is found your program should print it to the screen. (Note your program may call the function you wrote in Question 2 to do some of the work for you.)

The solution to these questions is given in listing 3.1. In the listing lines 1 to 12 presents the solution to question 1 above, lines 14 to 21 the solution to question 2, and lines 23 to 37 the solution to question 3.

```
1  public int SumOfDiv(int N)
2          {
3              int tmpAnswer = 0;
4              for (int i = 1; i <= N/2; i++)
5              {
6                  if (N % i ==0)
7                  {
8                      tmpAnswer += i;
9                  }
10             }
11             return tmpAnswer;
12         }
13
14 public bool IsPerfect(int N)
15         {
16             if (SumOfDiv(N) == N)
17             {
18                 return true;
19             }
20             return false;
21         }
22
23 public void FirstFive()
24         {
25             int counter = 0;
26             int Current = 2;
27
28             while (counter < 5)
29             {
30                 if (IsPerfect(Current))
31                 {
32                     Console.WriteLine(Current.ToString());
33                     counter++;
```

```
34                  }
35                  Current ++;
36              }
37          }
```

Listing 3.1: Solution to Assessment

The questions in the above assessment was constructed specifically to assess the use of the same underlying algorithmic control constructs that were practiced during the intervention. Firstly, the assessment does not present a recursive problem and thus does not require the use of 'recursion'. Secondly, the need to use 'structured decomposition' were eliminated by presenting the problem as three separate smaller problems. The researcher thus performed the structured decomposition for the students. The problem did however require some knowledge (two instances in the code) of 'functions and parameter passing'. Table 3.2 indicates the lines of code from this listing where specific algorithmic control structures as listed in Table 2.2 were used. As can be seen from this table the assessment required the use of the same algorithmic control structures that were used in the intervention (as discussed in section 2.6).

Table 3.2: Algorithmic Control Structures used in Assessment (Listing 3.1)

#	**Line numbers where used**
1.	all 1-37
2.	3,8,25,26,33,35
3.	4,6,16,28,30
4.	11,18,20,32
5.	16,30
6.	1,14,23 (given)
7.	none

3.4.5 Data Collection

Data were collected using the above mentioned data generating instruments. Data collection happened as follows:

- Firstly, before the intervention took place the students had already completed two of the summative semester tests for the subject. As discussed, the results of these two test were used to assign the students to either the experimental or the control group for the intended experiment.
- Secondly, the results of the additional assessment that the researcher designed were collected immediately after the intervention was completed.
- Thirdly, the qualitative questionnaire were completed by students who used the brain-compatible intervention material. This included students from both the experimental group and those of the control group who voluntarily accessed the brain-compatible material after the conclusion of the experiment. These answers were collected using surveymonkey (www.surveymonkey.com). Since participation was voluntary, some of the students invited to complete this survey did not do so. Many of the control group students also never exercised their right to also access the experimental material.
- Fourthly, the results of the final two semester test were collected at the end of the academic year. The first of these tests was written one week after the intervention, the second was written nine weeks after the intervention.

3.4.6 Data Analysis

The quantitative data were sent to the unit for statistical support for analysis and results were interpreted based on this statistical analysis. The results for the qualitative questionnaire was analysed using the reports provided by surveymonkey and all interpretation of these reports was done on a qualitative basis. The results are discussed in chapter 4.

3.4.7 Ethical Considerations

This research project received approval from the NMMU research ethics committee (Ref H12-EDU-ERE-031). In order to adhere to research ethics requirements all participation in the research was voluntary in nature. Students who did not form part of the experimental group were given full and unrestricted access to the same material used in the brain-compatible intervention directly after the completion of the non-summative test that was designed/intended to measure the intervention's effect and had such access for the remainder of the calendar year during which the intervention took place.

3.4.8 Validity and Reliability

As mentioned earlier, the qualitative instrument was adapted from an existing instrument that was designed to measure student motivation to learn. The quantitative data were analysed by the statistical support unit of the NMMU. Where appropriate specific statistics are mentioned during the discussion of results in the next section.

3.5 Limitations of Study

The biggest limitation of this study was the relatively small sample size (N=111), and the fact that only a single intervention was made. This contributed to the results being of moderate practical significance (Cohen's d = 0.41), ideally it would be desirable to have results of high practical significance (Cohen's d >0.8). Future research should attempt to use a larger sample size and, if possible, the experiment should be repeated as part of a longitudinal study over several years. A second limitation was the fact that the instruments were designed to measure the combined impact of the research. In hindsight it would have been preferable to gain some insight into the specific impact of individual principles as well. The biggest challenge in such a study would be to not inadvertently disadvantage students who form part of a control group in such research. During this study great care was taken to encourage control group students to also make use of the blended learning material after completion of the intervention. However, access logs in Moodle showed that most of them did not make use of this opportunity and many who did only did so briefly prior to answering the qualitative questionnaire.

3.6 Chapter Summary

This chapter presented the researcher's paradigmatic stance and research philosophy. The researcher identified himself as pragmatist and presented his research choices using the research onion, as suggested by (Saunders et al., 2007). The chapter presented the research methods followed in the study, as well as the design of the research intervention that was used in this study. The intervention took the form of brain-compatible e-learning learning lessons on selected fundamental programming concepts. This intervention was developed using a design science approach. During this design various brain-compatible principles which are usually used in a classroom setting, were applied to the developed intervention. The specific principles used, and how these principles was applied in the e-learning intervention, is presented in section 3.4.3. The discussion in section 3.4.3 thus answered the second secondary research question as defined in section 1.4, namely; *'How can the identified brain-compatible learning principles be applied in an e-learning environment?'*

Chapter 4

Results

This research used both quantitative and qualitative methods. A separate discussion of the results will therefore be presented for each of these two approaches.

4.1 Quantitative Results

As discussed in section 3.4.4, the quantitative data were gathered from two sources. Firstly, data was gathered in the form of an additional assessment developed to assess possible improvement in the use of underlying algorithmic control structures that were specifically practised in the intervention. The second source of quantitative data were the formal summative assessments students completed for the subject during the course of the year. Results for each of these are analysed separately.

4.1.1 Additional Assessment

The additional assessment was administered within a week after the completion of the research intervention. The intention of this assessment was to measure a possible immediate (short-term) effect of the intervention in the use of algorithmic control structures. Specifically the structures linked to learning outcomes for the "Algorithms and Problem Solving" core module, as discussed in Lunt et al. (2008). For convenience these structures is re-listed here in Table 4.1.

Table 4.1: Learning Outcomes: "Algorithms and Problem Solving"

#	Learning Outcomes
1.	Basic syntax and semantics of a higher-level language
2.	Variables, types, expressions, and assignment
3.	Conditional and iterative control structures
4.	Simple Input and Output
5.	Functions and parameter passing
6.	Structured decomposition
7.	Recursion

The specific outcomes used in the assessment are listed as outcomes numbers 1,2,3,4, and 5 in Table 4.1. However, since the students in the Technical Programming 1 subject had already done a previous programming course, mastery of basic syntax (outcome 1) was assumed and not analysed. Table 4.2 presents the results of the statistical analyses for both experimental and control groups for the use of constructs relevant to outcomes 2,3,4, and 5.

Outcome	BCE Group		Control Group		Mean score difference	t-value	p
	Mean	σ	Mean	σ			
2	1.84	1.00	1.53	1.08	0.31	1.55	0.12
3	2.93	1.60	2.65	1.58	0.28	0.92	0.36
4	0.76	0.91	1.05	0.90	-0.29	-1.66	0.10
5	2.27	1.30	2.52	1.21	-0.25	-1.03	0.30

Table 4.2: Results of statistical analysis for 'Algorithms and Problem Solving' learning outcomes 2 to 5 for brain-compatible education (BCE) experimental group (N=45) versus the control group (N=66) (df = 109)

The results presented in Table 4.2 are **not** statistically significant at all and show **no difference** between the experimental group and the control group. One can therefore conclude that **the intervention had no immediately measurable effect on student performance**.

4.1.2 Standard Summative Assessments

The results of the analysis of the four semester tests written by the students are shown in Table 4.3. As can be seen from this table the differences between the experimental group and the control group were negligible **prior** to the intervention (Tests T1 and T2). As mentioned before, the combined scores of T1 and T2 were used to sort students, and they were then assigned to one of the two groups based on alternating allocation. However, some students were allowed to move between groups for the student's convenience, and not all students assigned to the experimental group chose to participate in the entire exercise. All statistics related to students who opted out during the experiment were thus not included. This lead to unequal numbers of participants between the experimental group (N=45) and the control group (N=66).

Test	BCE Group		Control Group		Mean score difference	t-value	p
	Mean	σ	Mean	σ			
T1	58.20	18.78	58.76	21.28	-0.56	-0.14	0.89
T2	58.44	18.69	57.18	19.97	1.26	0.34	0.74
T3	77.56	20.77	70.61	24.44	6.95	1.56	0.12
T4	69.84	15.97	61.02	23.98	8.82	2.16	0.03*

Table 4.3: Results of statistical analysis for semester tests T1 to T4 percentage test scores for the brain-compatible education (BCE) experimental group (N=45) versus the control group (N=66)(df = 109; * statistically significant at 95% level of confidence,σ = standard deviation)

The results of test T3, which was written one week after the intervention, show that the experimental group had a mean score that was 6.95% higher than the mean score for the control group. However, this result is **not statistically significant**. This result is consistent with the result for the additional assessment that was report in the previous subsection. The results for test T4, which was written nine weeks after the intervention showed that the experimental group had a mean score that is 8.82% higher than the mean score of the control group. This result is **statistically significant** using a 95% confidence interval.

The *Cohen's d* value for this is 0.42. *Cohen's d* is an effect size that indicates the standardised difference between two means and is calculated as the difference between the means divided by the standard deviation. An effect size of less than 0.2 is considered a small effect size, i.e. one which is not significant, an effect size between 0.2 and 0.8 is considered as being moderately significant, while an effect size of 0.8 and greater is considered to be highly significant (Gravetter & Walnau, 2002). In this case the value of 0.42 is between 0.2 and 0.8 and the difference between the means, should thus be interpreted as being of **moderate practical significance**.

Based on the above, it is the researcher's opinion that **the intervention positively influenced the participants' future performance in the subject** and that **this positive effect took a few weeks to fully materialise**. This is possibly due to the fact that the intervention focussed on very fundamental logical constructs whose better understanding would transfer to other aspects of programming competency. It might also be that the patterning process took time to fully construct meaning out of the learning process, as discussed by Jensen (2008, p. 92).

4.2 Qualitative Results

In addition to the above quantitative results, the qualitative questionnaire was answered by a total of 74 of the participants.

4.2.1 Theme 1: Is the e-learning material different from 'normal' classes

The first thematic question, aimed to determine whether students thought the e-learning material was significantly different from their normal classes. The responses to questions relating to this theme are presented in Table 4.4. Additionally, Figure 4.1 and Figure 4.2 provides a graphical view of results for two of the sub-questions within this theme. These two sub-questions were selected because the researcher deemed them as being representative of the overall responses to sub-questions within this theme. As can be seen from the responses, the vast majority of the respondents (74 %)indicated that the e-learning content is different to their normal class activities.

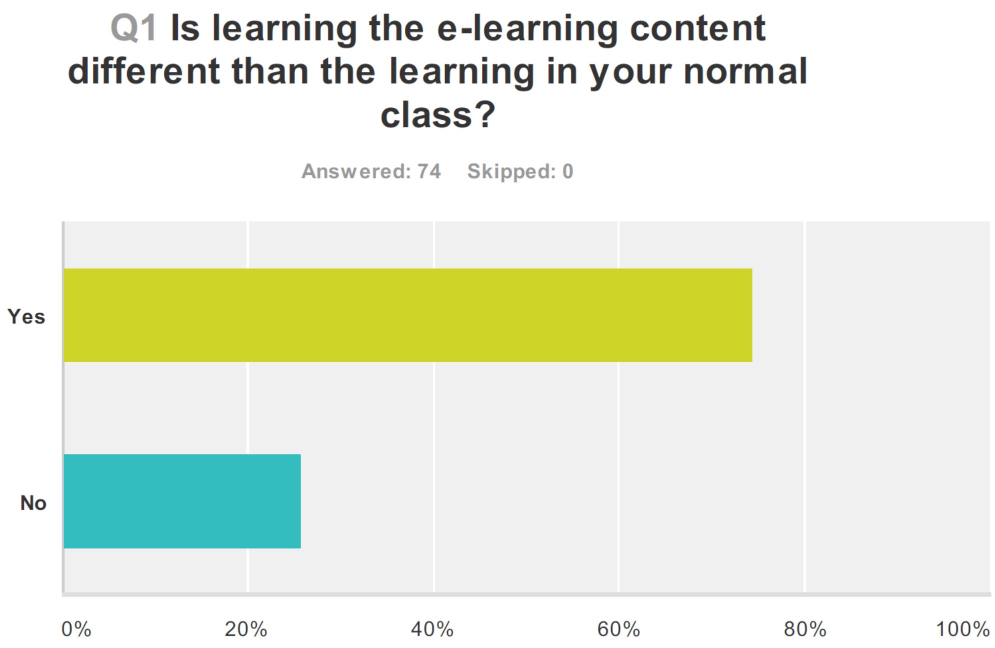

Figure 4.1: Responses to Question 1

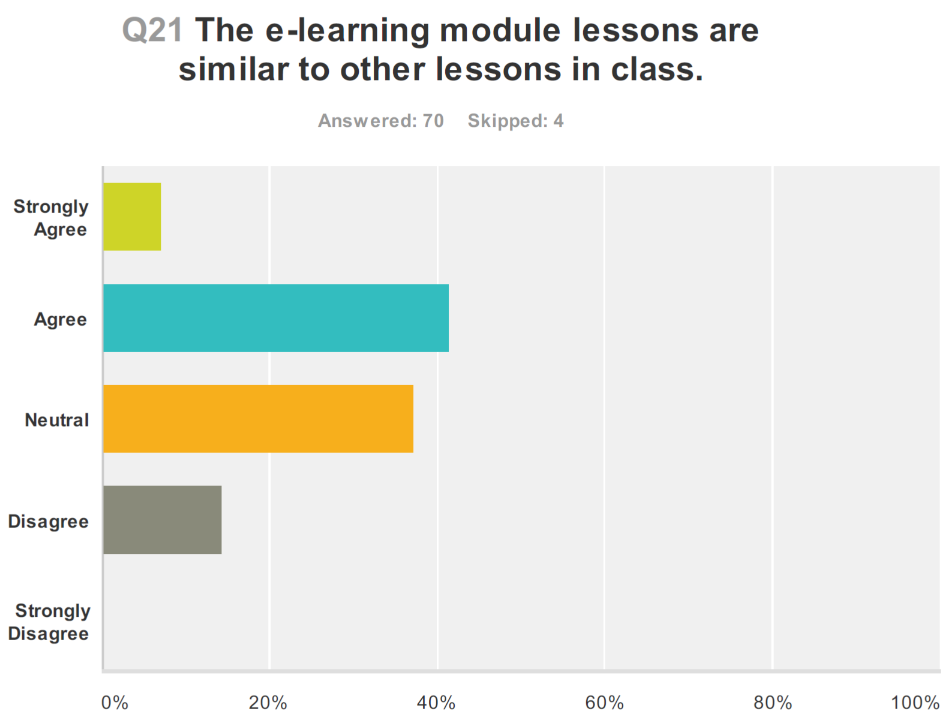

Figure 4.2: Responses to Question 21

Table 4.4: Theme 1 responses: Similarity of e-learning content to 'normal' classes

Questions	Responses	
Q 1. Is learning the e-learning content different to the learning in your normal class?	Yes	74%
	No	26%
Q 21. The e-learning module lessons are similar to other lessons in class.	Strongly Agree	7%
	Agree	42%
	Neutral	37%
	Disagree	14%
	Strongly Disagree	0%
Q 26. The lessons you have in class are more or less the same as the e-learning lessons.	Strongly Agree	1%
	Agree	39%
	Neutral	37%
	Disagree	22%
	Strongly Disagree	1%
Q 33. The e-learning lessons are similar to other subject lessons you have done before.	Strongly Agree	3%
	Agree	36%
	Neutral	60%
	Disagree	0%
	Strongly Disagree	1%

4.2.2 Theme 2: Is the e-learning material engaging (enjoyable)?

The second theme in the qualitative instrument aimed to determine whether students found the e-learning content engaging and enjoyable. The responses to questions relating to this theme are presented in Table 4.5. Additionally, Figure 4.3 and Figure 4.4 provides a graphical view of results for two of the sub-questions within this theme. Once again these sub-questions were selected for graphical presentation because the researcher deemed them representative of the learner response to the question posed by the overall theme. As can be seen from the responses depicted 78% of learner indicated that they **enjoy** this type of learning. Most, 90% indicated that they think other learners would also enjoy this form of instruction. Furthermore 75% of learners indicated that they would enjoy similar content in other subjects as well.

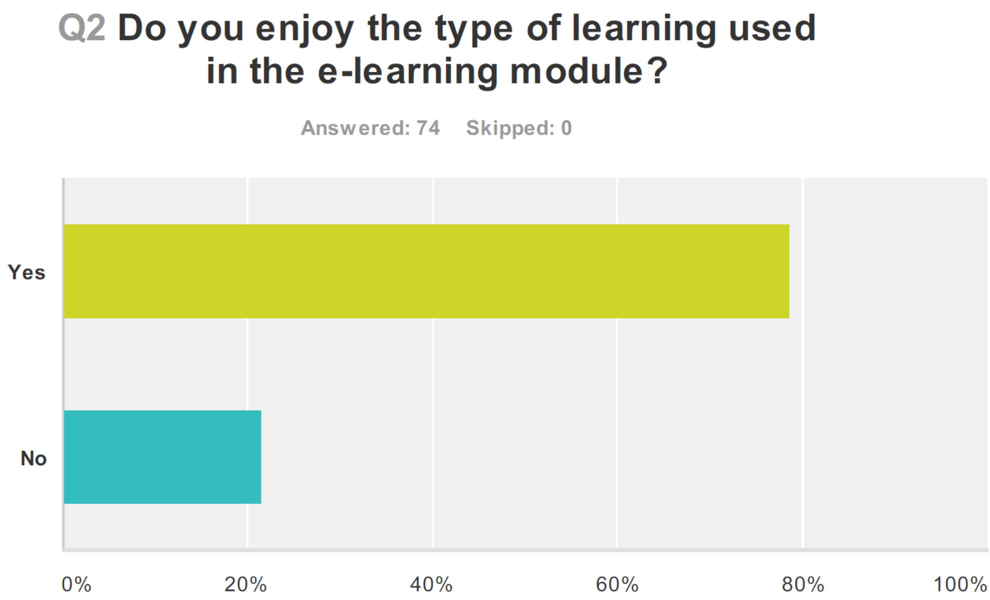

Figure 4.3: Responses to Question 2

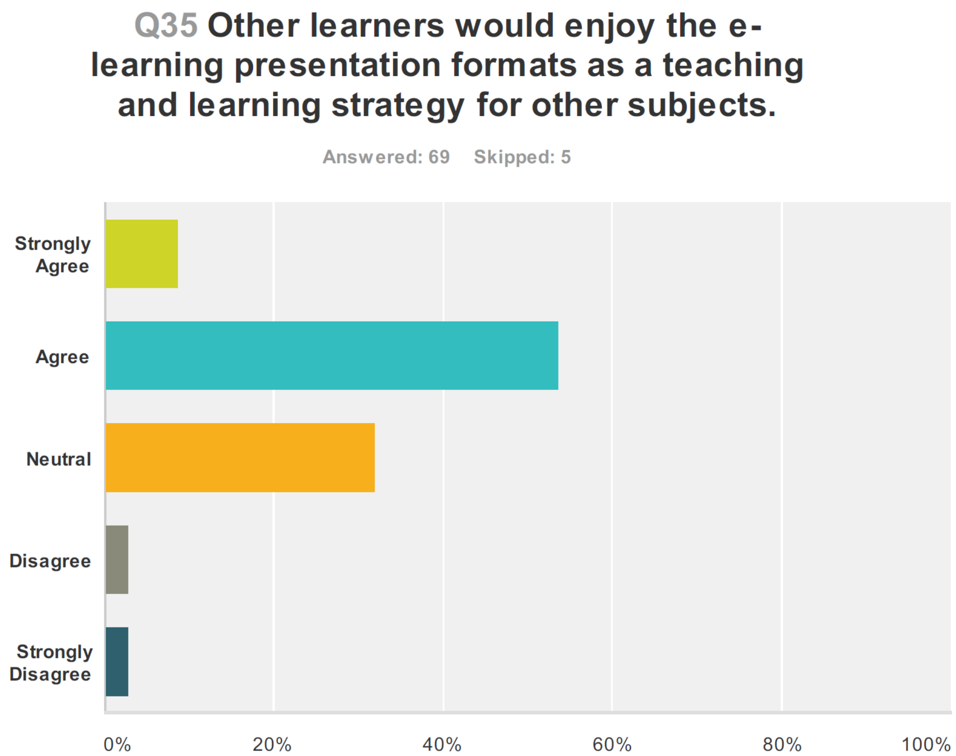

Figure 4.4: Responses to Question 35

Table 4.5: Theme 2 responses: E-learning content is engaging (enjoyable)

Questions	Responses	
Q 2. Do you enjoy the type of learning used in the e-learning module?	Yes	78%
	No	22%
Q 6. The e-learning material was engaging.	Strongly Agree	11%
	Agree	54%
	Neutral	34%
	Disagree	1%
	Strongly Disagree	0%
Q 15. Do you think other learners would enjoy this type of learning activity for other subject material?	Yes	90%
	No	10%
Q 17. You enjoyed working on the e-learning module lessons.	Strongly Agree	15%
	Agree	49%
	Neutral	26%
	Disagree	6%
	Strongly Disagree	4%
Q 18. Do you enjoy the e-learning lesson format as way of learning about a subject?	Yes	83%
	No	17%
Q 20. Could you see yourself working on other subjects using the e-learning lesson presentation method?	Yes	75%
	No	25%
Q 25. The e-learning lessons are boring and do not catch your interest.	Strongly Agree	2%
	Agree	14%
	Neutral	21%
	Disagree	54%
	Strongly Disagree	9%
Q 27. You often think about other things not related to the subject when you are busy with a e-learning lesson or media resource.	Strongly Agree	1%
	Agree	29%
	Neutral	40%
	Disagree	30%
	Strongly Disagree	0%
Q 28. You feel positive about your e-learning experience.	Strongly Agree	8%
	Agree	49%
	Neutral	33%
	Disagree	6%
	Strongly Disagree	4%

Continued on next page

Table 4.5 – continued from previous page

Questions	Responses	
Q 29. You enjoy the e-learning experience.	Strongly Agree	10%
	Agree	47%
	Neutral	35%
	Disagree	4%
	Strongly Disagree	4%
Q 35. Other learners would enjoy the e-learning presentation formats as a teaching and learning strategy for other subjects.	Strongly Agree	9%
	Agree	54%
	Neutral	31%
	Disagree	3%
	Strongly Disagree	3%
Q 36. You enjoy the e-learning lessons as a teaching and learning strategy to introduce the programming and logic topics.	Yes	80%
	No	20%

4.2.3 Theme 3: Do you prefer the e-learning approach over 'normal' classes?

The third theme in the qualitative instrument aimed to determine whether students would prefer the e-learning format over their normal classroom education. The responses to questions relating to this theme are presented in Table 4.6. A graphical representation of results for two of the sub questions within this theme is provided by Figure 4.5 and Figure 4.6. As can be seen from the responses the learners **did not** find the e-learning format preferable over normal classes. Instead, the vast majority (70%) indicated that they would prefer a mixture of **both** these formats. This was further confirmed by the fact that exactly 50 % of the students indicated a preference for the e-learning format over their normal classes whilst the other 50 % felt the opposite. In other words, these results confirm a definite preference for a **blended** format.

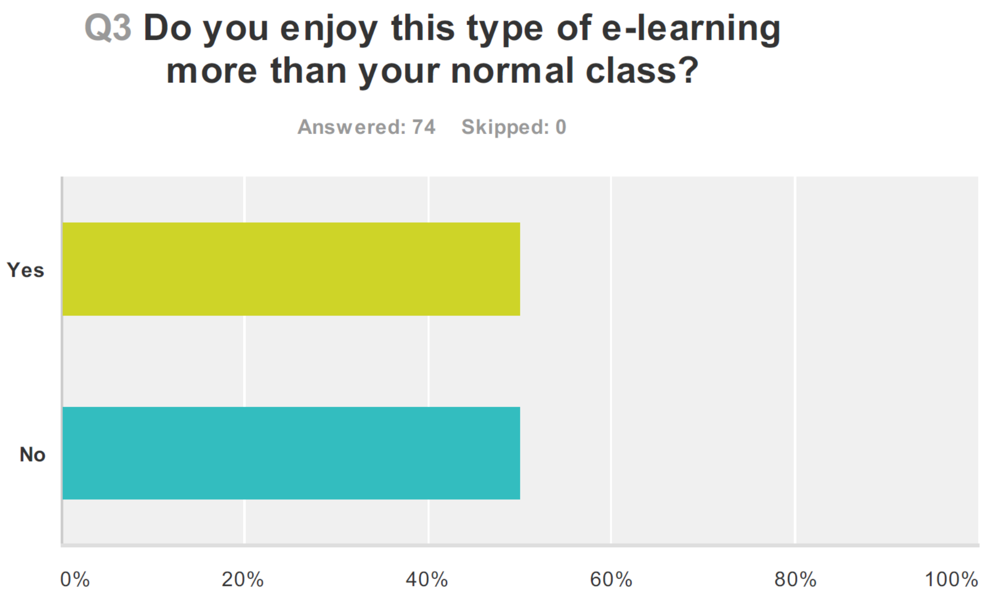

Figure 4.5: Responses to Question 3

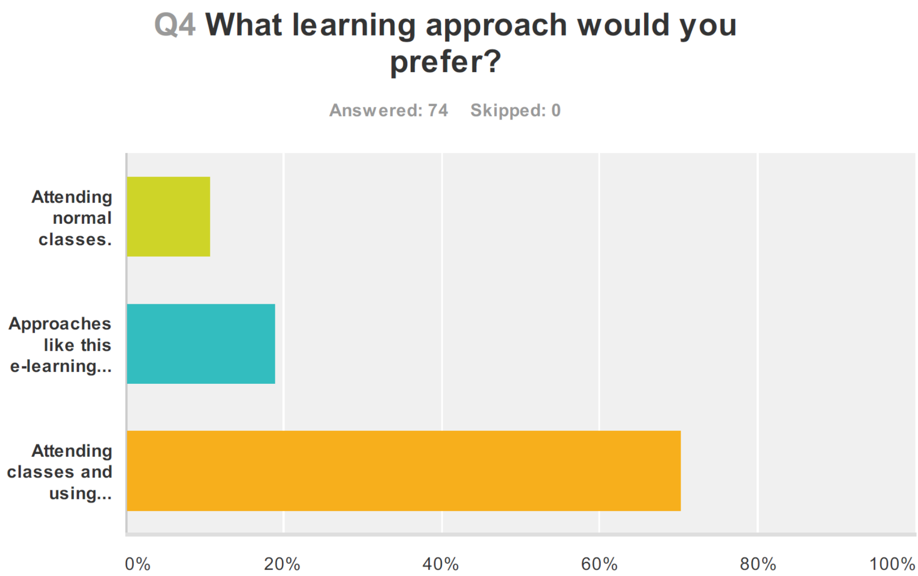

Figure 4.6: Responses to Question 4

Table 4.6: Theme 3 responses: E-learning content is preferred

Questions	Responses	
Q 3. Do you enjoy this type of e-learning more than your normal class?	Yes	50%
	No	50%
Q 4. What learning approach would you prefer?	Normal	11%
	E-learning	19%
	Both	70%
Q 16. Did the e-learning module lessons and resources help you learn in an interesting way?	Strongly Agree	7%
	Agree	56%
	Neutral	32%
	Disagree	4%
	Strongly Disagree	1%
Q 30. Doing the e-learning modules sure beats listening in class.	Strongly Agree	13%
	Agree	33%
	Neutral	26%
	Disagree	23%
	Strongly Disagree	6%
Q 31. You would prefer to work on the subject matter in a format which is not an e-learning method.	Strongly Agree	6%
	Agree	20%
	Neutral	41%
	Disagree	30%
	Strongly Disagree	3%
Q 32. You would prefer to do the subject matter using the e-learning approach rather than using other learning methods.	Strongly Agree	4%
	Agree	30%
	Neutral	45%
	Disagree	17%
	Strongly Disagree	3%

4.2.4 Theme 4: Was learning in the e-learning environment a positive experience?

The fourth theme in the qualitative instrument aimed to determine whether the e-learning format created a positive (non-threatening) learning environment. The responses to questions relating to this theme are presented in Table 4.7, whilst Figure 4.7 and Figure 4.8 provides a graphical view of results for two of the sub questions within this theme. Overall, the responses to the questions related to this theme was positive with 58% indicating they had a positive experience and only 10% indicated a negative experience. The students felt that the e-learning content allowed them to work at their own pace (68% positive and 27% neutral), the feedback improved their learning experience (50% positive and 39% neutral), they could relate to the examples (72% positive and 24% neutral), the colours used were appropriate (43% positive and 47% neutral), and navigation was easy (79% positive and 18% neutral).

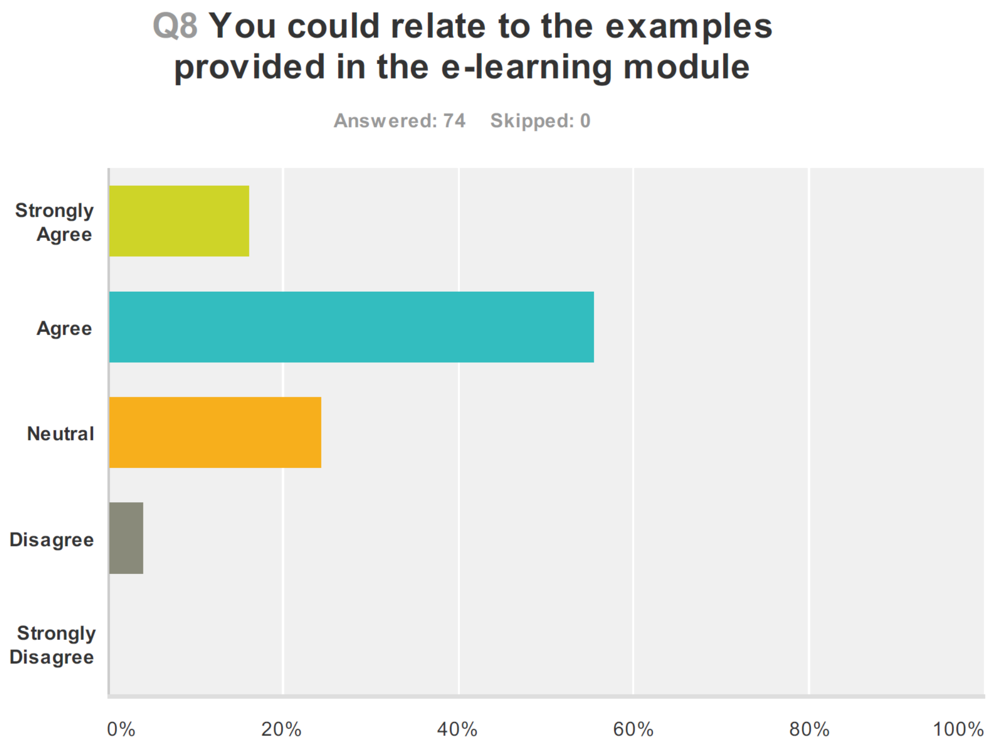

Figure 4.7: Responses to Question 8

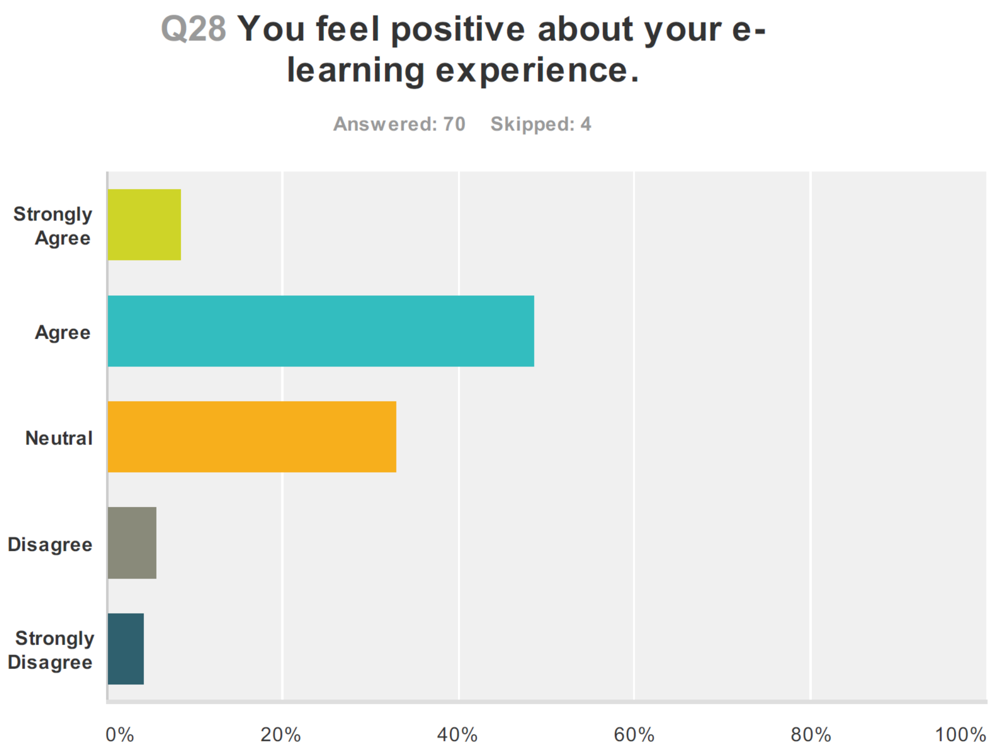

Figure 4.8: Responses to Question 28

Table 4.7: Theme 4 responses: E-learning content created a positive learning environment

Questions	Responses	
Q 5. The e-learning module allows you to work at a pace suitable to you.	Strongly Agree	19%
	Agree	49%
	Neutral	27%
	Disagree	5%
	Strongly Disagree	0%
Q 7. The feedback provided in the e-learning content improved your learning experience.	Strongly Agree	8%
	Agree	42%
	Neutral	39%
	Disagree	11%
	Strongly Disagree	0%

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Table 4.7 – continued from previous page

Questions	Responses	
Q 8. You could relate to the examples provided in the e-learning module	Strongly Agree	16%
	Agree	56%
	Neutral	24%
	Disagree	4%
	Strongly Disagree	0%
Q 10. The background colour of the module lessons was encouraging.	Strongly Agree	5%
	Agree	38%
	Neutral	47%
	Disagree	10%
	Strongly Disagree	0%
Q 11. The material was easy to navigate through.	Strongly Agree	21%
	Agree	58%
	Neutral	18%
	Disagree	3%
	Strongly Disagree	0%
Q 28. You feel positive about your e-learning experience.	Strongly Agree	9%
	Agree	49%
	Neutral	33%
	Disagree	6%
	Strongly Disagree	4%

4.2.5 Theme 5: Was the e-learning material 'rich' enough?

The fifth theme in the qualitative instrument determined whether the students were satisfied with the amount of 'rich' multimedia content in the e-learning intervention. The responses to questions relating to this theme are presented in Table 4.8. A graphical representation of results for two of the sub questions within this theme is provided by Figure 4.9 and Figure 4.10. The majority of students (57%) indicated that the content kept them interested in the course material, only 8% felt that it did not keep them interested. Very few (2%) of the students did not experience the animations used positively. The majority (75%) found that having multiple resources available helped to make the course content understandable.

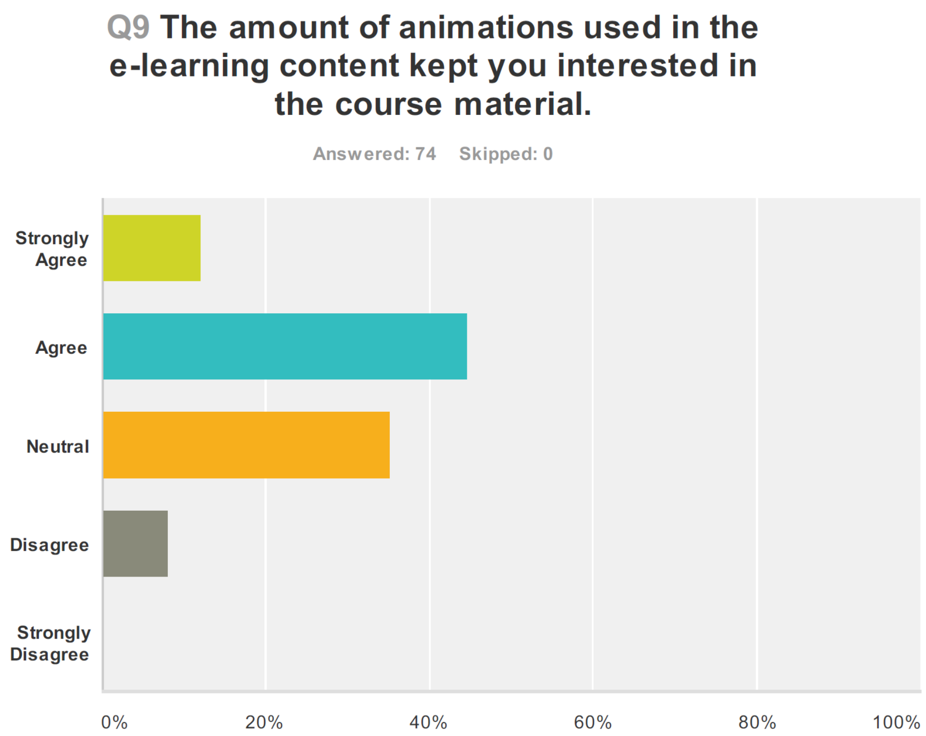

Figure 4.9: Responses to Question 9

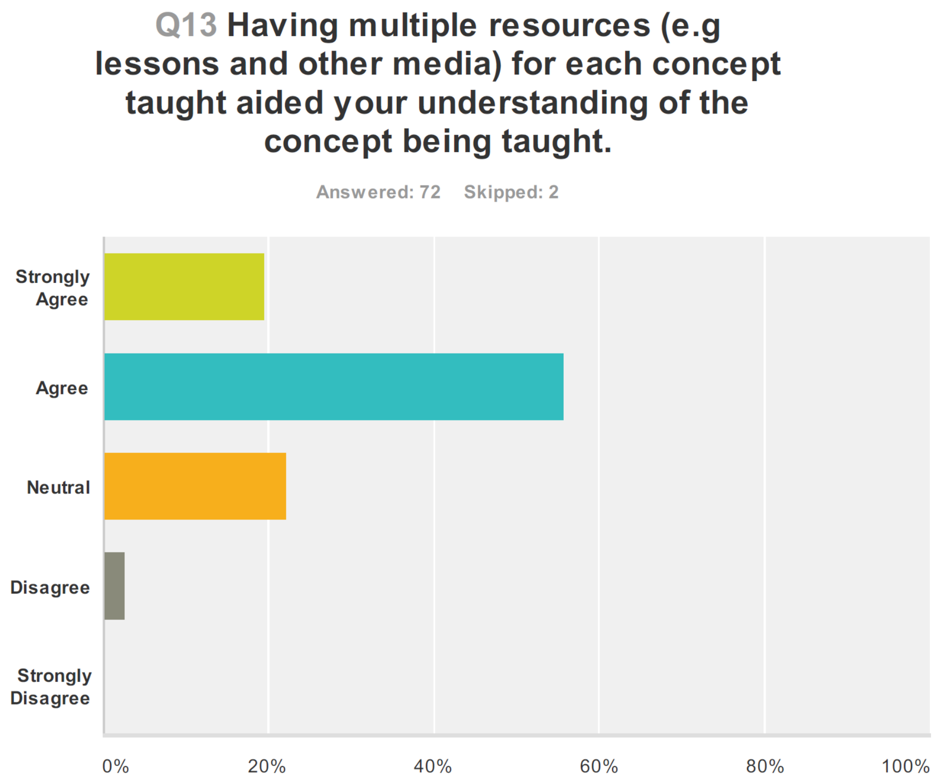

Figure 4.10: Responses to Question 13

Table 4.8: Theme 5 responses: Material was 'rich' enough (multimedia)

Questions	Responses	
Q 9. The amount of animations used in the e-learning content kept you interested in the course material.	Strongly Agree	12%
	Agree	45%
	Neutral	35%
	Disagree	8%
	Strongly Disagree	0%
Q 12. Fewer animations in the e-learning module lessons would have been preferable.	Strongly Agree	3%
	Agree	27%
	Neutral	33%
	Disagree	36%
	Strongly Disagree	1%
Q 13. Having multiple resources (e.g lessons and other media) for each concept taught aided your understanding of the concept being taught.	Strongly Agree	19%
	Agree	56%
	Neutral	22%
	Disagree	3%
	Strongly Disagree	0%
Q 14. The use of animations in the lessons helped explain the related lesson concepts	Strongly Agree	15%
	Agree	43%
	Neutral	40%
	Disagree	2%
	Strongly Disagree	0%

4.2.6 Theme 6: Did you *learn*?

The sixth theme in the qualitative instrument determined whether the students believed that they had *learned*. The responses to questions relating to this theme are presented in Table 4.9. A graphical representation of results for two of the sub questions within this theme is provided by Figure 4.11 and Figure 4.12. A very large majority of the students (86%) indicated that they felt that they have 'gained knowledge which is theirs' after completing the intervention. Interestingly, 45% felt they learned a lot of **new** things. Since all the concepts taught in the intervention were low level fundamental concepts which the students should already have mastered prior to the intervention, this probably indicates that many of these students view the novel application of the concepts, as used in the intervention exercises, as new knowledge. 56% of students indicated the intervention helped them remember concepts better, and 48% indicated that they learned **more** about fundamental programming concepts through the approach used in the intervention.

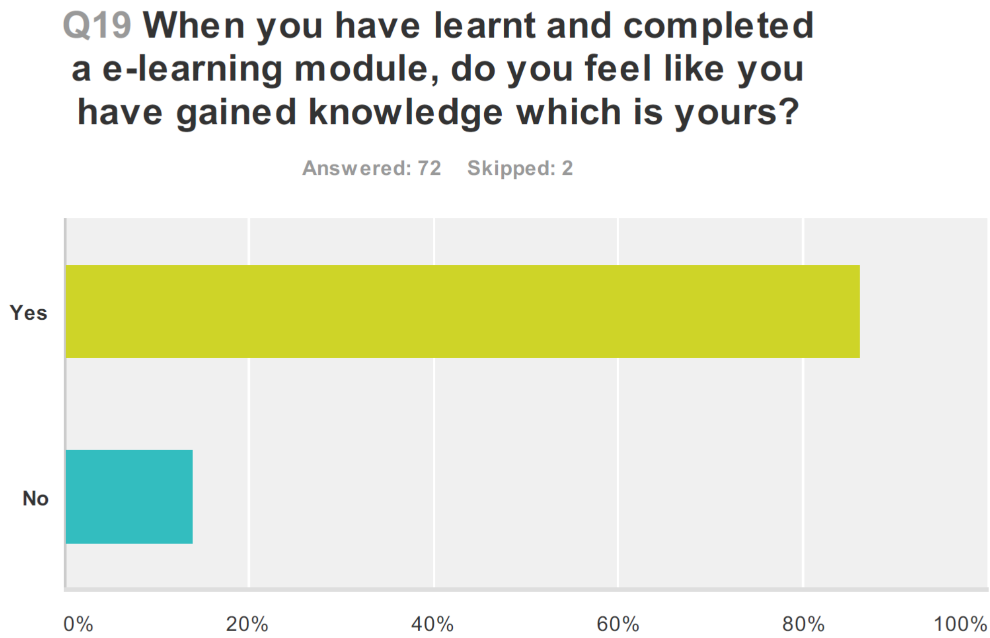

Figure 4.11: Responses to Question 19

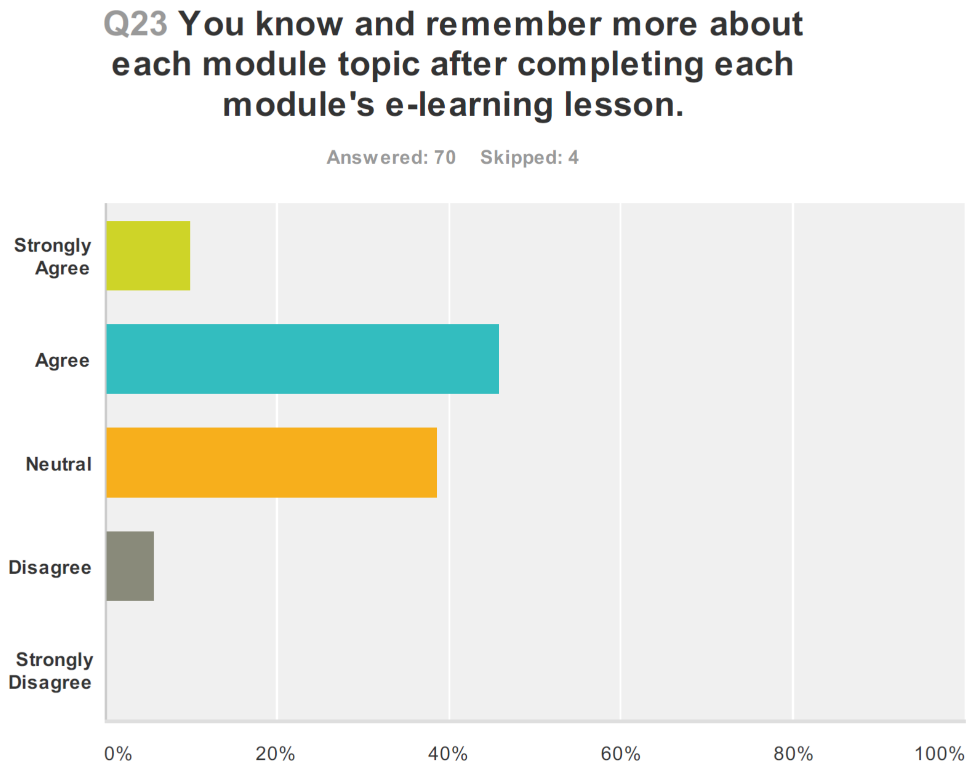

Figure 4.12: Responses to Question 23

Table 4.9: Theme 6 responses: Student feels that they have *learned*

Questions	Responses	
Q 19. When you have learnt and completed a e-learning module, do you feel like you have gained knowledge which is yours?	Yes	86 %
	No	14 %
Q 22. You learn lots of new things during the completion of the e-learning modules.	Strongly Agree	6%
	Agree	39%
	Neutral	49%
	Disagree	7%
	Strongly Disagree	0%
Q 23. You know and remember more about each module topic after completing each module's e-learning lesson.	Strongly Agree	10%
	Agree	46%
	Neutral	39%
	Disagree	6%
	Strongly Disagree	0%

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Table 4.9 – continued from previous page

Questions	Responses	
Q 24. You learn more about the programming topics when you complete a e-learning lesson than what you learn with other learning methods.	Strongly Agree	7%
	Agree	41%
	Neutral	36%
	Disagree	11%
	Strongly Disagree	4%
Q 34. You find the benefits of the e-learning modules (lessons and resources) to be valuable to your learning experience.	Strongly Agree	10%
	Agree	54%
	Neutral	31%
	Disagree	4%
	Strongly Disagree	1%

4.2.7 Open ended questions

The final section of the qualitative instrument allowed for open ended feedback from the learners. Many of the open ended responses that allowed for additional comments reflected that the students really enjoyed the fact that the e-learning material allowed them to work at their own pace. Unfortunately most of the answers given in the open ended section were very short single sentence answers. Some of the answers to the question 'what did you like about the e-learning material?' included (sic):

- 'Gives you step by step guide to solve problems and trace troughs'
- 'its straight forward, and you can work at your own speed.'
- 'it was nicely put out and it showed the trace trough the code and what happen'
- 'the fact that it taps into your logic and work through your understanding'
- 'It was very short and simple'
- 'It was straight to the point'
- 'Professional and to the point'

- ‘I liked how certain parts to focus on are highlighted and arrows navigate to show how something works’
- ‘The display of animation for something I had learnt in class.’
- ‘the way the quiz are done , makes learning more interesting’
- ‘The use of images and animations makes for a better understanding when explaining a certain topic.’
- ’Animations’
- ‘Doing things by yourself and asking for help when you are stuck’

None of the above answers were really surprising and these answers mostly confirmed the principles of brain-compatible learning.

To the question ’what did you not like about the e-learning material?’ answers included (sic):

- A few unnecessary repeat question...asking if i understood the method etc.
- ‘The work felt too simple’
- ‘Too many slides showing each step.’
- ‘A few unnecessary repeat question...asking if i understood the method etc.’
- ‘That its online and that you had to answer the questions online. I prefer having a lecturer lecture the material to me rather than sitting infront of a computer where no questions can be asked. It is more difficult to understand the work presented.’
- ‘I prefer a normal practical, because its difficult and forces me to research and study the topic, in which time i create study notes. By doing this over the week, i learn much more!’

4.3 Summary of Findings

The analyses of quantitative results showed that the intervention did not have an immediate effect on student performance. However, after a period of nine weeks a statistically significant improvement in student performance was noticed in the experimental group, which had a a mean score for their fourth semester test of the year that was 8.82% higher than the control group‘s mean score. This significance was at the 95% confidence level and had a Cohen‘s d value of 0.42, which indicated a moderate practical significance as noted earlier.

The qualitative result were similarly positive towards the brain-compatible intervention. The most significant result from the qualitative study, in the researcher’s personal opinion, is the fact that 86% of learners indicated a positive response to the question “When you have learnt and completed a e-learning module, do you feel like you have gained knowledge which is yours?”

Overall the data suggests the experimental results showed that the use of brain-compatible e-learning material could have a positive impact on the teaching of fundamental programming logic. However the study still had some limitations and more work is needed in future to confirm these results.

4.4 Chapter summary

This chapter presented the analyses of the results for the research intervention in this study. Firstly, the quantitative results showed a statistically significant improvement in student marks nine weeks after the intervention. However, this improvement was of small practical significance and further studies using a larger sample size and a longer intervention is recommended to confirm the results. The results of the quantitative analyses of the data thus answered the fourth secondary research question, as posed in section 1.4, namely; *‘What effect will the use of brain-compatible e-learning material have on the student achievement?’* Secondly, the qualitative results showed that students viewed the approached used in the intervention as a positive experience and that they felt they learned during the intervention. Students also had a clear preference for such e-learning as an **additional** resource, and **not** as a replacement for normal lectures. The qualitative result presented in this study answered the third secondary research question as defined in section 1.4 namely; *'What effect will the use of brain-compatible e-learning material have on the motivation of students to learn?'* The next chapter will discuss these findings and conclude the dissertation.

Chapter 5

Discussion and Conclusion

5.1 Introduction

The research in this dissertation set out to determine whether *e-learning material based on brain-compatible learning principles can improve the learning of students in the subject Technical Programming 1.* In order to do this a research intervention was designed in the form of e-learning materials that adheres to selected brain-compatible learning principles. The intervention was used in a controlled experiment as described in Chapter 3. The results of the experiment were presented in Chapter 4. In this chapter the research results are discussed as part of the conclusion of the dissertation. How the results of the research relate to the theory of brain-compatible learning is outlined and how the research questions that were posed in Chapter 1 were answered is revealed. The implications of the research findings are discussed, opportunities for future research are identified, and a final conclusion drawn.

5.2 Discussion

As discussed in section 3.4.4 of Chapter 3, the research intervention used in this study adhered to several brain-compatible learning principles. Due to fact that these principles were all used as part of the same integrated intervention design, it was not possible to measure the effect on student performance for any of these principles individually. The quantitative data could therefore only be meaningfully interpreted for the intervention as a whole. However, the qualitative data gathering instrument did attempt to measure student perception of some of the individual principles in addition to measuring student perception of the intervention as a whole.

The purpose of the first three themes of questions within the qualitative questionnaire was to determine the overall student perception of the e-learning intervention as compared to their normal classes. To this end the questions asked were aimed at determining whether or not students experienced the e-learning intervention as *different* from their normal classes, whether or not they *enjoyed* the e-learning format, and finally whether or not they *preferred* the e-learning format to normal classes. The respective answers to these questions indicated that the majority (74%) of students experienced the e-learning as different from normal class (section 4.2.1), most students enjoyed this format (78%) and thought other students would enjoy it too (90%) (section 4.2.2), but students did not prefer the e-learning format over normal classes, instead the majority (70%) indicated they would prefer to have both formats (section 4.2.3). These indicated preferences support the findings of previous research that showed students generally still prefer access to face-to-face instruction but enjoy e-learning as an *additional* resource (Artino, 2010; Paechter & Maier, 2010; Means et al., 2009).

The fourth qualitative theme aimed to evaluate whether or not students experienced the e-learning intervention as a *positive* (non-threatening) experience. As discussed in section 4.2.4 only 10% indicated that they had a negative experience, whilst the majority (58%) indicated an overall positive experience. As discussed in Chapter 2, 'learning is enhanced by challenge and inhibited by threat' (Fogarty, 2009; Jensen, 2008; Craig, 2003; Caine & Caine, 1991). The facts that most students found the experience to be positive (58%), felt that they were allowed to work at their own pace (68%), could relate to the examples (72%), and found navigation easy (79%), all support the researcher's opinion that the intervention provided such a non-threatening environment. Furthermore, several open-ended answers such as liking 'the fact that I worked out everything on my own' and 'doing things by yourself and asking for help when you are stuck' also indicates that the intervention still contained a certain degree of challenge, which also adheres to the 'challenge-threat' principle.

The fifth qualitative theme dealt with how 'rich' the e-learning material was and included questions regarding how the students experienced the use of animations, as well as the support for multiple modalities and opportunities to learn. The use of such 'rich' e-learning material relates to several of the brain-compatible learning principles that were discussed in Chapter 2. According to (Jensen, 2008, pp. 55) one should "attract the brain with movement, contrast, and colour changes. Our visual system is designed to play close attention to those elements because they each have the potential to signal danger." These animations and colour changes were also intended to allow the learners to 'involve both focused attention and peripheral perception' as suggested by Fogarty (2009), Jensen (2008), Materna (2007), Craig (2003), Caine and Caine (1991). Results of the analysis of student perception of animations showed a strong preference for the use of such animations. Specifically, the results of question Q9 showed that only 8% of students did not feel that the animations kept them interested in the material, and the results of question Q14 showed that only 2% of students that the animations did not help in the explanation of concepts. Additionally several of the students also specifically mentioned their liking of the animations in the open-ended response section.

In the case of the research intervention used in this study, the way in which the lessons were laid out using both graphical representations of algorithms and actual code listings as components in the animations also encouraged the students to 'simultaneously perceive and process parts and wholes' (Fogarty, 2009; Craig, 2003; Caine & Caine, 1991). The same lesson material was also made available in a variety of formats which provided 'support for different learning style preferences' and made lessons 'multifaceted' as recommended by Jensen (2008), Materna (2007), Craig (2003). Therefore, in addition to confirming student affinity for the use of such animations, this research also demonstrated *how* several brain-compatible learning principles can be applied in an e-learning lesson aimed at teaching basic programming logic. The same techniques might also be applicable to teach material from other fields of study.

The sixth and final qualitative theme dealt with the question the researcher considered most important, namely whether the students felt that they had *learned*. Once again the responses to the questions in this theme were generally positive. As mentioned before, most significant in the researcher's opinion is the fact that 86% of learners indicated that they 'gained knowledge which are now their own'. This was further supported by the fact that 56% indicated that they 'know and remember *more* about the topics after completion of the e-learning lessons' and that 54% saw the e-learning as 'valuable learning experience'. However, these results were not supported by the initial quantitative data which was gather shortly after the intervention. The quantitative data only showed a statistically significant improvement in student achievement nine weeks after the intervention took place.

The results of the fourth semester test the students wrote for the subject showed that the experimental group had a mean score that was 8.82% higher than the control group's mean score. This was significant at the 95% confidence level and had a Cohen's d value of 0.42, which indicated a moderate practical significance as noted earlier. This delay before realizing an improvement is also predicted by the literature about brain-compatible learning. According to (Jensen, 2008) the new learning will not become something the brain 'knows it knows' until the learning was (1) reinforced in the learner's dependent modality (the learner must hear it, or see it, or feel it, for example in a test score, or as an emotion on someone's face, etc.), (2) be reinforced through repetition (the amount of repetition will vary from one individual to another), and (3) be validated for an unspecified length of time. Learning occurs through a process of 'patterning' (Fogarty, 2009; Jensen, 2008; Craig, 2003; Caine & Caine, 1991) and this 'involves both conscious and unconscious processes' (Fogarty, 2009; Materna, 2007; Caine & Caine, 1991). Many of the unconscious processes take place whilst the learner sleeps (Fogarty, 2009), and since 'each brain is unique' (Fogarty, 2009; Jensen, 2008; Craig, 2003; Caine & Caine, 1991) it is difficult to predict how long it will take for new knowledge to be integrated with existing patterns. Effective lessons should thus also give learners both the time and the opportunity to make sense of their experiences through reflection in order to find and construct meaningful connections (Gülpinar, 2005).

In addition to the above findings, the qualitative questionnaire also allowed open-ended feedback regarding features of the e-learning lessons that the students liked or disliked. Several students used this to indicate that they enjoyed the 'short and simple' or 'straight to the point' nature of the lessons. This could be interpreted as an endorsement of the decision to use several small tasks in the intervention, each of which takes between 5 and

10 minutes to complete, as recommended by (Jensen, 2008). Students also indicated that they liked that the lessons in the online material required them to 'work out everything on my own' and 'doing things by yourself and asking for help when you are stuck'. This aligns with the brain-compatible learning principle which states that 'learners need to recognize and connect patterns by themselves (learning only happens from what is actively, personally, and specifically experienced)' (Jensen, 2008; Materna, 2007; Craig, 2003; Smilkstein, 2003).

In general the research findings thus showed that the use of brain-compatible learning principles in an e-learning intervention for the purpose of teaching fundamental programming logic had a positive effect on both student motivation and student achievement in the subject *Technical Programming 1.* These results confirmed the findings of the literature as discussed in Chapter 2. The next section will discuss how the specific research questions posed in this dissertation was answered by the research.

5.3 How the research questions were answered

The primary research question to be answered by this research, as defined in Chapter 1, section 1.4, was: *Can e-learning material based on brain-compatible learning principles improve the learning of students in the subject Technical Programming 1?*

In order to answer this primary question, four secondary research questions were identified. To answer the first of these secondary research questions a review of appropriate literature was conducted. This literature review is presented in chapter 2 and introduced the field of brain-compatible learning. The concept of blended learning was also discussed in chapter 2 and elaborations made on the reasons for using such a blended learning approach. Finally the purpose of logical problem solving in programming education was discussed before providing examples of how identified brain-compatible learning principles *could* be used in programming education in section 2.6.1. The presentation of these principles in section 2.6.1 answered the first secondary research questions, namely; *'Which brain-compatible learning principles could be used in the explanation of subject material dealing with algorithms and problem solving?'*

In chapter 3 the design of the research intervention that was used in this study was presented. The intervention took the form of brain-compatible e-learning learning lessons on selected fundamental programming concepts. This intervention was developed using a design science approach. During this design various brain-compatible principles which are usually used in a classroom setting, were applied to the developed intervention. The specific principles used, and how these principles was applied in the e-learning intervention, is presented in section 3.4.3. The discussion in section 3.4.3 thus answered the second secondary research question, namely; *'How can the identified brain-compatible learning principles be applied in an e-learning environment?'*

In order to answer the third secondary research question, a research instrument to determine the effect that brain-compatible e-learning material would have on student motivation to learn, had to be developed. The researcher adapted an existing instrument from (Du Plessis, 2010) to this purpose. The design of this instrument is presented in section 3.4.4. The instrument was answered by 74 of the participating students and a detailed analyses of their answers is presented in Chapter 4, section 4.2. The analyses of results showed that the brain-compatible blended learning material had positive impact on student motivation to learn. Students liked the format and felt that it helped them to learn and that the learning became 'their own'. However, students also clearly indicated that they would not want such brain-compatible e-learning material *instead* of their normal classes, but would prefer it in addition to their normal classes. It is thus clear that a *blended learning* would be the approach preferred by the learners. These qualitative results thus answered the third secondary research question, namely; *'What effect will the use of brain-compatible e-learning material have on the motivation of students to learn?'*

The fourth, and final, secondary research question was answered through the analyses of quantitative data. This data was gathered using both a special assessment that was developed specifically for this purpose, and the formal summative assessments that formed part of the subject offering for the students. The design of this additional assessment is discussed in chapter 3 section 3.4.4. An analyses of the quantitative data is presented in chapter 4, section 4.1. This analyses shows that the use of the brain-compatible e-learning material had no immediate effect on student achievement. However, after a period of nine weeks a statistically significant effect was observed. The students who used the brain-compatible e-learning material had a mean average score that was 8.82% higher than the mean score of the control group. This result is *statistically significant* using a 95% confidence interval and is of moderate practical significance (Cohen‘s d = 0.42). This thus answered the final secondary research question, namely; *‘What effect will the use of brain-compatible e-learning material have on the student achievement?’*

Collectively, the results of the four secondary research questions allowed the researcher to answer the primary research question affirmatively. *‘**Yes**, e-learning material based on brain-compatible learning principles **can** improve the learning of students in the subject* Technical Programming 1’

5.4 Implications of the research

There has been a phenomenal increase in the use of e-learning and or blended learning in recent years. It has thus become imperative for lecturers to learn how to incorporate e-learning into their courses. Most lecturers already believe that technology use has added value to teaching and learning but acknowledge that they have to learn more in order to use e-learning effectively in their own courses (Mahdizadeh et al., 2008).However, while e-learning does not fall into any specific learning theory, any lecturer who adopts it must still use it in ways that are consistent with existing learning theories (Mbati & Minnaar, 2015; Torrao & Tiirmaa-Oras, 2007). As noted earlier, brain-compatible learning is not a *learning theory* but rather presents a collection of *learning principles* that could be used irrespective the specific learning theory to which a lecturer subscribes. This makes brain-compatible learning an ideal pedagogical basis for the design of e-learning material. The results of this study, therefore, have several implications for the use of brain-compatible learning principles in an e-learning environment. The research has shown that:

- it is *possible* to use brain-compatible learning in an e-learning environment
- using brain-compatible learning principles in the design of e-learning

lessons could have a positive effect on both student motivation to learn and their achievement

- e-learning material should not be used to replace face-to-face instruction, but should be used in addition to face-to-face instruction
- multiple short lessons in a variety of modalities work well
- carefully planned animations can incorporate several brain-compatible learning principles
- lecturers should not expect immediate results from such interventions because patterning takes time

Finally, as mentioned by Artino (2010), successful e-learning experiences leads to a higher likelihood of students choosing e-learning again in future. The researcher believes that the use of brain-compatible learning principles contributed to making this intervention a positive e-learning experience which could encourage students to embrace the use of e-learning in future.

5.5 Suggestions for future research

As only 'moderate' practical significance of the statistically significant quantitative data were achieved, and results which are 'highly significant' in terms of practical significance would provide a stronger argument for the use of brain-compatible elearning material, using larger sample sizes and longer intervention cycles are options that should be considered for further research (Gravetter & Walnau, 2002; Kenny, 1987). This study also applied the identified brain compatible principles only in a single context within the e-learning environment. Future studies could thus also investigate using these principles in different ways and in different contexts in a variety of e-learning materials. The researcher believes that the same principles can also be applied to e-learning interventions in other fields of study and future research could explore such use.

5.6 Conclusion

The findings of this study, namely that brain-compatible learning principles can be used in an e-learning environment and that e-learning material which adheres to brain-compatible education principles have a positive effect on *Technical Programming 1* students' achievement and motivation to learn, appear to be meaningful contributions to the current debate on blended learning. These findings, although limited in size and scope and require deeper exploration, are well motivated both qualitatively and quantitatively in terms of students comments and statistical data (probability values and practical significance). As many educational institutions worldwide are, in part, responding to the ever increasing demand for higher education through the increased provision of e-learning material to augment traditional classroom instruction, these findings are of current importance. While the caveat remains that e-learning material need to be developed within pedagogical frameworks, it is reassuring that it appears that the principles of brain-compatible learning are sufficiently malleable to be used in most pedagogical contexts.

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Appendix A - Qualitative research instrument

Qualitative Questionnaire submitted for ethical clearance for the study entitled: The effectiveness of brain-compatible blended learning material in the teaching of programming logic

1. Is learning the e-learning content different than the learning in your normal class?

   ☐ Yes

   ☐ No

2. Do you enjoy the type of learning used in the e-learning module?

   ☐ Yes

   ☐ No

3. Do you enjoy this type of e-learning more than your normal class?

   ☐ Yes

   ☐ No

4. What learning approach would you prefer?

   ☐ Attending normal classes.

   ☐ Approaches like this e-learning module.

   ☐ Attending classes and using e-learning as additional material.

5. The e-learning module allows you to work at a pace suitable to you.

   ☐ Strongly Agree

   ☐ Agree

   ☐ Neutral

   ☐ Disagree

   ☐ Strongly Disagree

6. The e-learning material was engaging.

   ☐ Strongly Agree

   ☐ Agree

   ☐ Neutral

   ☐ Disagree

   ☐ Strongly Disagree

7. The feedback provided in the e-learning content improved your learning experience.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

8. You could relate to the examples provided in the e-learning module

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

9. The amount of animations used in the e-learning content kept you interested in the course material.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

10. The background colour of the module lessons was encouraging.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

11. The material was easy to navigate through.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

12. Fewer animations in the e-learning module lessons would have been preferable.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

13. Having multiple resources (e.g lessons and other media) for each concept taught aided your understanding of the concept being taught.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

14. The use of animations in the lessons helped explain the related lesson concepts.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

15. Do you think other learners would enjoy this type of learning activity for other subject material?

- ☐ Yes
- ☐ No

16. Did the e-learning module lessons and resources help you learn in an interesting way?

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

17. Did you enjoy working on the e-learning module lessons?

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

18. Do you enjoy the e-learning lesson format as way of learning about a subject?

- ☐ Yes
- ☐ No

19. When you have learnt and completed a e-learning module, do you feel like you have gained knowledge which is yours?

- ☐ Yes
- ☐ No

20. Could you see yourself working on other subjects using the e-learning lesson presentation method?

- ☐ Yes
- ☐ No

21. The e-learning module lessons are similar to other lessons in class.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

22. You learn lots of new things during the completion of the e-learning modules.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

23. You know and remember more about each module topic after completing each module's e-learning lesson.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

24. You learn more about the programming topics when you complete a e-learning lesson than what you learn with other learning methods.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

25. The e-learning lessons are boring and do not catch your interest.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

26. The lessons you have in class are more or less the same as the e-learning lessons.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

27. You often think about other things not related to the subject when you are busy with a e-learning lesson or media resource.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

28. You feel positive about your e-learning experience.

☐ Strongly Agree

☐ Agree

☐ Neutral

☐ Disagree

☐ Strongly Disagree

29. You enjoy the e-learning experience.

☐ Strongly Agree

☐ Agree

☐ Neutral

☐ Disagree

☐ Strongly Disagree

30. Doing the e-learning modules sure beats listening in class.

☐ Strongly Agree

☐ Agree

☐ Neutral

☐ Disagree

☐ Strongly Disagree

31. You would prefer to work on the subject matter in a format which is not an e-learning method.

☐ Strongly Agree

☐ Agree

☐ Neutral

☐ Disagree

☐ Strongly Disagree

32. You would prefer to do the subject matter using the e-learning approach rather than using other learning methods.

☐ Strongly Agree

☐ Agree

☐ Neutral

☐ Disagree

☐ Strongly Disagree

33. The e-learning lessons are similar to other subject lessons you have done before.

- ☐ Much Better
- ☐ Better
- ☐ Neutral
- ☐ Worse
- ☐ Much Worse

34. You find the benefits of the e-learning modules (lessons and resources) to be valuable to your learning experience.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

35. Other learners would enjoy the e-learning presentation formats as a teaching and learning strategy for other subjects.

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

36. You enjoy the e-learning lessons as a teaching and learning strategy to introduce the programming and logic topics.

- ☐ Yes
- ☐ No

37. Do you think this e-learning course's material and presentation has benefited you in any way?

- ☐ Yes
- ☐ No

38. What did you like about the e-learning material?

____
____
____
____
____

39. What did you NOT like about the e-learning material?

____
____
____
____
____

40. Are there any additional comments you wish to add about the material, its presentation and its content?

____
____
____
____
____

Appendix B - Student consent form as displayed on intervention web site

Consent form for research study - 12 August 2013

Dear student,

You are invited to take part in a research study which aims to investigate the effectiveness of certain e-learning materials in helping you learn. Your participation in this study is entirely voluntary and you may choose to not participate at any time should you want to.

Once you have completed your assignment you can submit it to the link which is labeled "I agree to participate" or should you wish to not participate and thus only do the required "normal" practical work you may submit to the alternative link provided.

*By submitting my work to the "**I agree to participate**" link I hereby declare that:*

1. *I was given the opportunity to ask questions and all these questions were answered satisfactorily.*
2. *No pressure was exerted on me to consent to participation and I understand that I may withdraw at any stage without penalisation.*
3. *Participation in this study will not result in any additional cost to myself.*
4. *My own identity will not be published in any form.*
5. *I give the researcher permission to access my semester test & exam marks in order to measure whether this material has helped me learn.*

- Practical Assignment - 12 August 2013File
- I agree to participate - Upload Task 1Assignment
- I agree to participate - Upload Task 2Assignment
- I DO NOT want to participate - Task 1Assignment
- I DO NOT want to participate - Task 2Assignment