An Information Technology Instrument to Enhance the Development of Abstract Thinking for Object-Oriented Programming

by

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Declaration

I, Moabi Saul Kompi, student number [redacted], declare that this dissertation, submitted for Magister Technologiae: Information Technology at the Central University of Technology, Free State represents my own research. This research has not been submitted previously at any other institution for academic examination towards any qualification. Furthermore, every attempt was made to ensure the inclusion and acknowledgement of all sources used or quoted in this dissertation by means of complete references. Finally, this research work was possible under the wonderful supervision of Mr Leon Grobbelaar as well as Dr Marita Oosthuizen, of the Department of Information Technology, at the Central University of Technology, Free State.

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Abstract

Object-oriented Programming (OOP) is a programming paradigm that offers a more natural and intuitive way to describe, for example, instances of variables by relating them to real world objects with attributes through the creation of classes and their associated instances, called objects. The creation of classes, instantiation of objects, inheritance of other classes and composition are significant abstract topics in OOP that distinguish it drastically from its counterpart, i.e. structured programming. OOP is very abstract in nature and requires abstract cognitive skills, similar to the skills needed to perform well in mathematics, for the proper comprehension of the theoretical constituents associated with OOP as well as the practical application thereof.

Several programming languages that implement the OOP paradigm, for example Java, facilitate class creation via abstract data types (ADT), which further points to the abstract nature of this paradigm.

The main objectives of this research were to:

- determine the theoretical concepts related to abstract thinking ability in the human brain and how it is stimulated;
- determine what evaluation instruments related to assessing abstract thinking ability exist currently and of what an IT software-tool aiming to develop abstract thinking ability should comprise;
- determine the development of a software tool that will stimulate and assist the development of abstract thinking abilities within the users thereof;
- provide evidence regarding the effects of such an intervention on the abstract thinking abilities of the users thereof and on that of the academic performance of the users thereof in OOP.

To develop such an intervention, the researcher investigated available literature, employed a registered psychologist and incorporated available games, exercises, and questions to bring out the full potential of the working intervention.

An experimental case-study research design was used for this project. The GSAT assessment tool formed part of the evaluation tools with the aim to evaluate both the

non-verbal (abstract reasoning) as well as the verbal skills of a control and an experimental group.

The mixed method methodology, consisting of both quantitative and qualitative research approaches, was used to conduct this research study.

Furthermore, the resulting intervention that was developed and deployed as part of this study includes the functionality to data collection, which was analysed, deliberated upon and presented. The objective was to prove the hypothesis that:

A custom software tool, designed, developed, introduced and deployed, specifically to stimulate certain cognitive processes in the human brain, has the ability to improve students' abstract thinking ability and a direct effect on students' performance in OOP when used for a determined period.

The data of the pre and post-psychometric assessments indicated measurable improvement in the abstract thinking abilities of the experimental group when compared to that of the control group. Subsequently, the institutional assessment results regarding OOP supported this data and indicated improvement in the academic performance of the members of the experimental group in OOP as a subject, when compared to that of the members of the control group.

The study concluded with the presentation of a set of guidelines for developers who aim to develop interactive Information Technology tools to stimulate abstract thinking abilities within the users thereof.

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This Master's Programme has been a long and interesting journey. It is extremely important that I thank all those who have directly or indirectly helped and supported me in making this dissertation possible.

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List of Abbreviations

3D	Three Dimensional
a	Average
aa	Above average
ADT	Abstract Data Type
ba	Below average
CTS	Concurrent Triangulation Strategy
d	Decrease
EEG	Electro Encephalography
FET	Further Education and Training
fMRI	Magnetic Resonance Imaging
GengQ	Game Engagement Questionnaire
GexpQ	Game Experience Questionnaire
GSAT	General Scholastic Aptitude Test
GUI	Graphical User Interface
HEI	Higher Education Institutions
i	Increase
ICT	Information and Communication Technology
IGPE	Interactive Graphics Programming Environment
IRB	institutional review board
IT	Information Technology
ITDP	Independent Two-group Design with Pretesting
ITS	Integrated Tertiary Software

ITSs	Intelligent Tutoring Systems
MEG	Magneto Encephalography
MFCs	Mass Flow Controllers
MOU	Memorandum of Understanding
MS	Microsoft
Oid	Overall Increase or Decrease
OOP	Object-oriented Programming
ORACLE	A Data Base Management System & Programming Language
PDRLS	Pathfinder Diagnosis and Remedial Learning System
PESCO	Programa de Estimulacion Cognitiva
QuizJET	Java Evaluation Toolkit
RDBMS	Relational Database Management Systems
s	Same
S.A.	South Africa
SA	Student Assistant
SES	Sequential Explanatory Strategy
SES	Sequential Exploratory Strategy
SI	Supplementary Instructor
SP	Structured Programming
SQL	Structured Query Language
tDCS	Transcranial Direct Current Stimulation
TMS	Transcranial Magnetic Stimulation
UEQ	User Experiences Questionnaire
UoT	Universities of Technology

waa	Well above average
wba	Well below average

CHAPTER 1

INTRODUCTION

1.1 Introduction and Background to the Study

Information and Communication Technologies (ICTs) have come to play a significant role in most people's lives. Various authors reiterate this and there are many examples throughout literature of how ICTs can better the lives of individuals. Ratshefola (2011), amongst others, asserts that most Government Institutions, Institutions of Higher Education, and Basic Education use ICTs which drive vehicle development, communications, control our homes, and have generally revolutionised the way we live.

Given the immense scope of ICT usage and the huge demand for skilled professionals in this area, Government Departments and sections of the Private Sector face critical shortages of skilled IT professionals at different levels of their operations (Daniels, 2007). Thus, Institutions of Higher Education as well as private training colleges are facing huge challenges to educate, train and produce skilled professionals to help fill this void. According to Calitz, Greyling & Cullen (2014), professionals with ICT skills will ultimately play an important role in ensuring overall economic growth and socio-economic development in South Africa, Africa and around the globe. This is confirmed by Perry (2011) who states that education is one of the South African President's five short-term priorities - especially the training and development of skills in areas such as ICTs, Science and Engineering.

Universities of Technology (UoTs) focus strongly focus on practical technical skills development. Enrolling for a course is the right and the choice of the relevant student and it is not the intention of the researcher to downplay the importance of any non-science graduates in society. However, there is indeed a growing need for more skilled professionals in the field of engineering and technology as can be seen from the statistics of a study that was conducted at a UoT over a period of 3 years (2013 to 2015). The data showed that Management Sciences produced 42% of graduates, Humanities 49% and Engineering, Science and Technology only 9%

(Appendix C). As a result, IT departments within companies are experiencing difficulties finding people with sufficient knowledge and experience in this field, and since many institutions use the latest technologies that ICTs have to offer, there is an eminent need for software developers who can develop, install and maintain applications for desktops and wireless devices (Hashim, 2015).

Even though the Information Technology (IT) profession provides diverse opportunities consisting of several areas such as Networking Specialists, Computer Technicians, Software Developers, etc., this study will focus on the field of Software Development, i.e. Programming.

According to Farell (2011), Computer Programming is a set of instructions that tells a computer what to do. This requires mandatory in-depth knowledge of programming principles, language syntax, and relevant programming language structures is for any software developer to successfully develop, install and maintain software applications. As a result, becoming a software developer, or computer programmer can be interesting, but challenging and sometimes even frustrating for students (Farell, 2011), especially because of the two Computer Programming paradigms widely taught by Higher Education Institutions (HEIs), namely Structured programming and Object-oriented programming (OOP).

A particular barrier that students often face in programming, involves learning and adapting to new ways of conceptualizing programming concepts as well as a shift in the way they had been learning up to Grade 12. Evidence shows that OOP subjects require a high level of abstract thinking skills from students and demands both practice and intensive effort (Rogerson & Scott, 2010).

The next section will give an overview of the problem statement of this study.

1.2 The Problem Statement

As mentioned above, the shortage of skills in ICTs and the low throughput of students in the field of Technology are facts that cannot be ignored. Furthermore, research indicates that students either shy away from enrolling for Software Development courses or, alternatively, underperform in successfully applying and implementing the OOP paradigm (Calitz et al., 2014).

According to Kramer (2007), a student's performance in OOP, i.e. the ability to conceptualize certain programming concepts, is influenced directly by his/her ability to think in an abstract manner. However, other factors that could play a role in a student's academic performance include, amongst others, social problems, economic challenges and the study environment. Whilst acknowledging these factors, one should just indicate that they influence all areas of study, not only OOP and thus fall outside the scope of this research.

As OOP is largely abstract in nature, it seems that finding a way to improve abstract thinking might positively influence students' understanding and application of OOP. That is the problem under investigation in this research study.

The following two sections provide a clear description of the main aim, objectives and research questions of this study.

1.3 The Research Questions

Taking the factors mentioned in paragraph 1.2 into account, the primary aim of this study is to answer the following main research question:

- How can a software tool be developed and specifically designed to stimulate certain cognitive processes with the aim to improve students' abstract thinking ability and thereby have a positive effect on their academic performance in OOP?

The following sub-questions follow from the main question:

- How is abstract thinking stimulated and developed?
- What evaluation instruments or methods for empirically evaluating abstract thinking ability currently exist?
- Of what should an IT tool with the aim of engaging and developing abstract thinking ability comprise?

The main research question and corresponding sub-questions give rise to the study's hypothesis:

A custom software tool, specifically designed, developed, introduced and deployed to stimulate certain cognitive processes of the human brain, can improve students' abstract thinking ability and have a direct effect on students' performance in OOP when used for a determined period.

1.4 The Objectives of the Study

Complementing the main research questions and sub-questions posed in the previous section, the following are the objectives of this study:

- to determine:
    - the theoretical concepts related to abstract thinking;
    - how abstract thinking is stimulated and developed;
    - what evaluation instruments or methods for evaluating abstract thinking ability empirically are there currently; and
    - of what an IT software-tool with the aim to engage and develop abstract thinking ability should comprise.
- to develop and implement a software tool that will help develop abstract thinking ability.
- to provide empirical evidence of the effects of the intervention on the abstract thinking ability of the users thereof, and the subsequent effect on their academic performance in OOP.
- to give insights about the relevance and applicability of the named intervention and its impact on the user.

1.5 The Preliminary Literature Review

1.5.1 Object-oriented programming

OOP requires abstract cognitive skills, similar to the skills needed to perform well in mathematics (Armoni, 2013). In recent years, it (OOP) has become the preferred programming teaching paradigm over structured programming, since the prior provides a more natural and intuitive way of describing real-world objects through creating classes and their associated instances (Xihui, 2010). Several programming languages that implement the OOP paradigm, for example Java, facilitate class creation via abstract data types (ADT), which hide their implementation from clients or other classes. ADTs provide implementation-independent interfaces to their clients, thus eliminating the problem of rewriting the other classes' code if the data implementation changes.

The abstract nature of the OOP paradigm requires a particular abstract thinking ability for performing computational functions. As pointed out earlier in the text, class creation, instantiation of objects, inheritance of other classes, and composition distinguish OOP from its counterpart, i.e. structured programming (Ehlert & Schulte, 2009). However, it is not only these that distinguish OOP, but implementation also. The OOP paradigm stores data by using the concept of "objects" consisting of different attributes that will ultimately contain the relevant data. Abstraction, Inheritance, Polymorphism and Encapsulation form the four fundamental principles of the OOP paradigm (Farrell, 2008; Amstrong, 2011; Cankaya, Yuksel, Koyun & Yigit, 2015).

OOP, as an eminent programming methodology in Software Application Development, has amongst others, the following significant features:

- It makes use of the concept of abstraction, referred to as a process that ignores non-essential details about the artefact, and strongly focuses on important properties and method headers that are, for example, required during the planning phase of phenomenon development.
- It employs polymorphism, which is the ability of objects of classes, belonging to the same parent class, holding functions or methods that have the same name, but behaving differently and appropriately when used by a particular object.
- It allows the re-use of sections of code with relative ease. Re-usability means that one section of code can be written and then employed repeatedly by different procedures/modules to perform required calculations and actions, instead of re-typing certain segments of code in different code procedures or modules.
- It embraces the concept of encapsulation, which is the object's ability to hide its internal implementation from the user - also known as information hiding.

- It uses inheritance that indicates the capability of an object to inherit another object's attributes.

Most of the aspects mentioned in this section regarding OOP, comprise some level of abstract notion or idea.

1.5.2 Object-oriented programming: Challenges at Higher Education Institutions

Many Higher Education Institutions (HEIs) present IT qualifications with the aim to train and equip students to become Software Developers, ready for continued in-job training and development (UNISA, 2016; UFS, 2016; UNW, 2016; CUT, 2016). However, owing to the strict criteria for admitting students to these qualifications, HEIs as well as prospective students face certain challenges when it comes to student recruitment for the relevant qualifications.

In most cases, prospective students must have obtained quite a high mark in Mathematics at Grade 12 level. Although some UoTs do take in students with a high mark in Mathematical Literacy, many HEIs do not even consider a student with Grade 12 Mathematical Literacy (UNISA, 2016; UFS, 2016; UNW, 2016; CUT, 2016; VUT, 2016; TUT, 2016). Since the pass rate for grade 12 Mathematics in South Africa is generally very low, according to Scielo (2012: online), Businesstech (2016: online) and DoE (2016), only a small number of students qualify to be enrolled for IT qualifications at HEIs.

Another problem with which students are faced is that most do not have the opportunity to learn anything about programming at school level. Very few schools in South Africa have the subject Information Technology, and therefore most first-year students must learn about programming without any background thereof (Thinyane, 2010).

Since UoTs contain both structured and OOP principles of programming that students must understand and be able to apply effectively in order to progress to the next year of study, the researcher decided to conduct his research at a UoT in South Africa rather than another kind of HEI. Programming requires students to first understand the building blocks and then spending long hours in the programming environment, starting by applying the basic programming principles practically and working their way up to more complex programming solutions. Many students simply give up in the process because they do not understand the abstract principles that underpin OOP (Hadar & Hadar, 2007; Govender, 2010).

In an effort to improve students' academic performance, many UoTs opt for the appointment of Supplementary Instructors (SIs) and Student Assistants (SAs) to assist students in problematic areas of programming modules, by providing extra classes and individual support. Supplementary Instructors explain concepts to students in their home language, e.g. South Sotho. According to Souriyavongsa et al. (2013), this, in some cases, leads to a better understanding of the subject matter as opposed to situations in class where the language of teaching and learning is English. Nevertheless, despite measures in place to assist students, the drop-out rate of students enrolled for modules where OOP is taught is still very high (Carvalho, 2015). One might conclude that assistance provided to students is merely addressing the symptoms of an inherent problem, and not the cause.

It is important to note that when teaching students programming, the structured programming paradigm is initially as significant as the OOP paradigm. Many of the important features of structured programming, such as learning how to declare variables, and select and repeat control structures play important roles in learning the fundamentals required to understand programming in the OOP paradigm.

Having lectured first-year students over many years, it is the researcher's opinion that although students tend to cope with structured programming, they lack the ability to comprehend the programming concepts, principles and methodology of OOP. If one takes an overview of the academic performance, over time, at the UoT where this study was conducted, it is clear that students perform better in tests and assignments related to structured programming than OOP. This is evidenced by the fact that the average mark for a main test for structured programming was 53%, whilst the average mark over the same period for the main test that covered OOP was 41%. In addition, complaints and queries from first-year IT students at this particular UoT indicated that students understood structured programming concepts and their application much better than those of OOP.

1.5.3 Abstract Thinking

Abstract thinking or thoughts involve a number of different cognitive processes working together to accomplish a particular goal. Tsai and Thomas (2011) maintain that abstract thinking evokes schematic processing and focuses primarily on placing information in a larger perspective, to help people understand the bigger picture. Similarly, Chapman et al. (1997) and Lister (2011), assert that abstract thinking is the brain's highest level of cognitive functioning that performs crucial and critical processes, e.g. performing calculations and sorting numbers. These thinking abilities enable individuals to use concepts to construct and comprehend generalizations (Tsai & Thomas, 2011). Thus, individuals with abstract thinking skills have the ability to categorize, conceptualize and draw conclusions easily from processes that are considered complex (Lister, 2011).

According to Napier and Luguri (2013), abstract thinking skills can be improved by learning how to demonstrate abstract concepts attractively, efficiently and effectively, by using available concrete elements. They assert that if an abstract mind-set is developed or stimulated well, people will achieve greater potential, which will then shape, enhance and improve their performance in all walks of life.

One should mention that there is another form of thinking, namely concrete thinking, which does not form part of the current study. Concrete thinking, which primarily focuses on the physical world, is the opposite of abstract thinking (Napier & Luguri, 2013; Tsai & Thomas, 2011). With this type of thinking people, for example, concentrate more on the facts of physical objects and their precise definitions. To demonstrate the difference between abstract and concrete thinking one can consider the following examples:

- An abstract thinker might categorize soda as a beverage, whereas the concrete thinker might see soda as a specific brand of beverage, e.g. Coke.
- An abstract thinker might categorize a carrot as a vegetable, whereas the concrete thinker might see a carrot as orange of colour.

As mentioned earlier, OOP, like Mathematics, is very abstract in nature and demands abstract cognitive skills. This means that students need the ability to think in an abstract manner or engage abstraction skills. Kramer (2007) points out that abstract thinking ability is essential for manipulating and reasoning about abstractions for programming languages that incorporate OOP. Unfortunately, many students lack abstraction skills and find abstract concepts challenging to comprehend (Alexandron, Armoni, Gordon & Harel, 2014). Klingberg (2010) shows that brain training can improve cognitive performance.

Working memory, another critical part of the brain, plays a vital role with regard to knowledge acquisition. Shipstead, Redick and Engle (2012) aver that the learning of mathematics and computer languages have been connected to the working memory's diverse skills capability. Thus, a close relationship seems to exist between working memory and abstract thinking ability (Raghubar, Barnes & Hecht, 2010). Thus, working memory and the development thereof are also relevant to this study.

Chapter 2 will provide more details.

1.5.4 Neuroplasticity

Recent research has revealed that human brains adapt and change during the process of learning by creating new links between neurons, known as motor training-induced neuroplasticity (Bezzola, Merillat & Jancke, 2012).

The term neuroplasticity comes from the root words "neuron" and "plastic". Neurons are the nerve cells in the human brain, made up of axons and dendrites, as seen in Figure1.1. Axons and dendrites are linked together by a small space, known as *synapse*. Plastic, in neuroplasticity, refers to moulding, modifying or sculpting. The term, neuroplasticity thus refers to the potential of the brain to reorganize neurons and neural links and its ability to create new neural pathways to adapt as required. Neuroplasticity can thus be seen as neurological changes in the brain, i.e. the brain's way of tuning itself to meet particular requirements (Nicholls, 2017: online). Neuroplasticity can also be described as the human brain's natural ability to change its structure and form new connections throughout a person's life, as a result of, amongst others, one's life experiences (Perwej & Parwej, 2012).

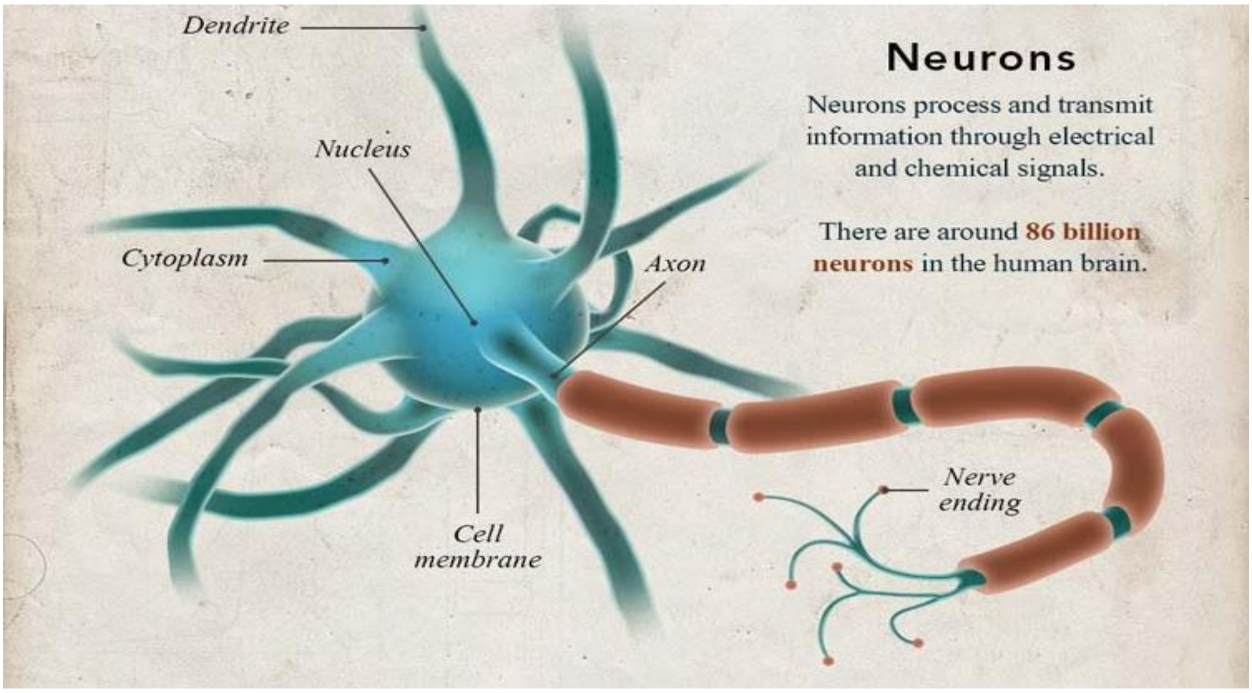

Figure 1.1: A simplified overview of a neuron (Pearce, 2015)

According Perwej and Parwej (2012), specific neurons, called grandmother cells, in different parts of the brain represent certain concepts. These neurons work together to accomplish certain tasks, such as completing patterns, functions, and reaching set goals. The human brain is, therefore, a complicated communication system capable of solving complex problems within a short time and storing solutions, in the form of concentrated chemical substances, in the synapses of the neurons. In addition, Klingberg (2010) explains that training the brain's neurons improves performance in a wide range of functions and the improved performance is associated with neuronal changes from intracellular levels to the functional organization of the cortex. In other words, the human brain constantly learns how to learn (Acharya, Shukla, Mahajan, 2012). Thus, abstract thinking abilities, in the form of working memory, could be stimulated and improved upon.

The information presented in this section is of critical importance, since this research study focuses on finding ways to improve student learning in an OOP environment.

1.6 Scope and Delineation

The main purpose of this research is to develop a software tool to engage students' ability to think in an abstract manner, improve this ability, incorporate successful conventional study methods to enhance a better grasp of OOP, thereby improving academic performance.

Empirical data was gathered from students who were selected purposively, i.e. students enrolled for a module with the focus on OOP, at a UoT in the Central part of South Africa. The researcher reviewed literature on the characteristics of existing and available tools before developing the software tool (from now on called the intervention). Moreover, the researcher consulted a qualified psychologist who provided continued insights on abstract thinking abilities, psychometric instruments available for stimulation of abstract thinking abilities, and the development of such instruments.

1.7 The Research Design and Methodology

The study uses a qualitative research approach, together with relevant quantitative elements. A combination of the qualitative and quantitative approaches is known as the mixed-method approach. Chapter 3 contains a comprehensive discussion of this approach as well as the instrument used to gather data.

Convenience sampling, with elements of probability sampling, is used as a specific group of students from a particular UoT is targeted. Participants in convenience sampling are chosen based on convenience to the researcher, relative to the proximity of the case related to this study. Probability sampling suggests that every individual in the population has an equal chance to be selected as part of the study (Acharya, Prakash, Saxena and Nigam, 2013).

In line with the qualitative methodology, the study employed the following methods:

- Information sessions were conducted with the participants to establish trust and answer relevant questions regarding the particular software intervention.
- Focus group interviews were conducted to gather the required information from the experimental group participants with the aim to improve, among

other things, the look and feel (interface), as well as the functionality and usability of the software intervention.
- The researcher did observations within a controlled environment to obtain tangible information regarding participants' overall behavior, reactions and understanding of the intervention's functionalities and reliabilities.

The following quantitative data gathering methods were used:

- Participants wrote two psychometric tests to collect data regarding abstract reasoning abilities related to their studies – one test prior to and one after engagement with the software intervention.

- Questionnaires were used to collect data in a real world setting about the practicality of the newly developed intervention, i.e. how participants experienced the use of the software tool.

De Vaus (2001), defines *research design* as the inclusive approach to integrate all the different components of the study in a logical manner with the aim to address all research questions effectively and coherently. This study largely followed an experimental design with components of a case study.

Participants were observed and experiments done to test how the constructed intervention performed within a specified and controlled environment. Experiments continued until sufficient data was generated and gathered to address the posed hypothesis and answer the research questions. The data could even indicate more experimentation/exploration. As the research was performed within a specified setting, using human participants, elements of a case study design were also included in the overall research design.

1.8 The Chapter Division

Chapter 1 provides a background, problem statement, research questions and aims of the study. It furthermore, provides a short literature overview as well as the main research methodology that was employed in this study. It concludes with an overview of the chapters in this dissertation.

Chapter 2 presents a more comprehensive literature review, which provides evidence with regard to earlier tools developed by other researchers in support of a proposed tool that was developed during the course of this study.

Chapter 3 provides insights of the research methodologies employed in this study.

Chapter 4 elaborates on the development of the software intervention as well as the process of data collection and analysis as applied in this study.

Chapter 5 focuses on the deliberation, analysis, and presentation of the data collected during the entire project.

Chapter 6 summarises and concludes the study by presenting the findings of the study, as well as providing recommendations for further research.

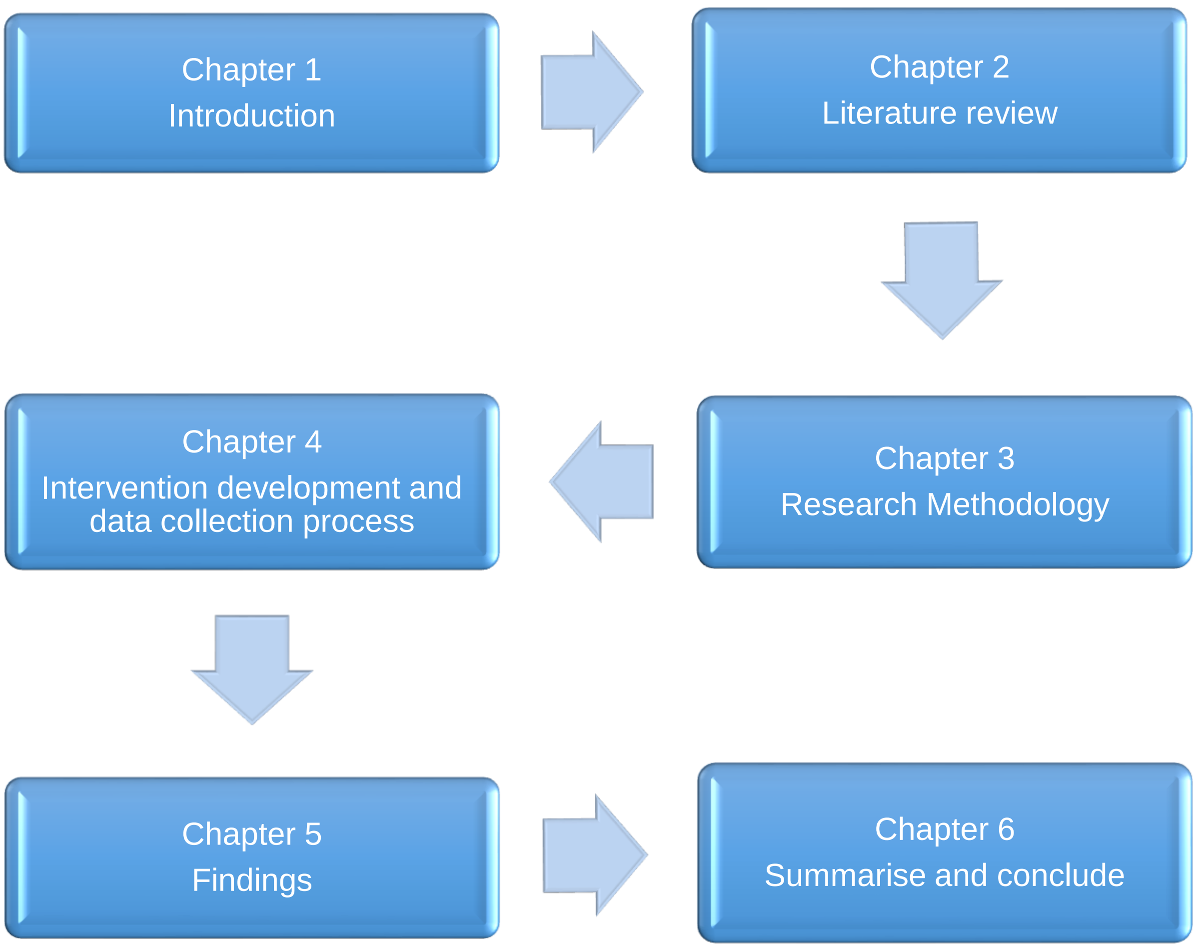

Figure 1.2: Project map summarizing the content of the chapters

1.9 Conclusion

Chapter 1 provided the reader with an overview of the study by describing the research questions, aims and contribution of the study. Furthermore, the research design and methodologies were outlined briefly. The chapter concluded with an overview of the chapters in this dissertation.

The following chapter will provide a literature overview of important concepts, the nature of abstract thinking, tools developed to stimulate abstract thinking abilities and expand further on working memory and neuroplasticity.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature suggests that many universities face the challenge of first-year students struggling to conceptualize OOP philosophy and concepts. However, these challenges are not limited to UoTs only. For instance, Pereira Jr. and Rapkiewickz as quoted by (Hernandezet al., 2010) assert that students at Brazilian Universities within IT and Computer Science related courses usually encounter difficulties in adapting to the abstract process of elaborate algorithms, which leads to high failure and drop-out rates.

2.2 Piaget's Developmental Theory

The complexity of human nature has seen psychologists scientifically investigating human behaviour and development (Horowitz, 2014). The key components of Piaget's theory are the nature of cognitive development, behaviour, and development of human intelligence (Fischer, 1980). According to Ojos (2008), Piaget used a conversation procedure, common in psychiatric questioning, as a means to investigate the thinking ability of children. Piaget's theory is important to this study, since it aims to improve the abstract thinking ability of students. According to Piaget, there are four fundamental stages of cognitive development in children (Ojos, 2008; Newriver.edu, 2016; Verywell.com, 2016):

- The sensorimotor stage:
  A child's mental and cognitive attributes development, during this stage, is evidenced by sensory experiences and the manipulation of objects. Children learn that objects are separate entities that exist on their own, outside of individual perception and they attempt to attach names and words to these objects. Intelligence is demonstrated through symbolic thought and the improvement of language ability. Although memory and imagination are developed, self-centred thinking predominates logical thinking which is limited.

It is in this stage that children make use of available materials such as blocks, sand, and water to engage in problem-solving tasks.

- The Preoperational Stage:

  At this stage, children often struggle to conceptualize abstractly and needs concrete physical situations. Especially, when objects are classified in simple ways and according to their important features.

- The concrete operational stage:

  This stage is characterized by the remarkable cognitive growth shown by children by logically and systematically manipulating symbols related to concrete objects. Furthermore, in terms of problem-solving, the mentioned activities provide children with enough skills and knowledge to make abstract ideas concrete, and to consider the mathematical ideas and concepts as useful tools. It is in this stage that self-centred thinking reduces.

- The formal operational stage:

  The ability to make logical use of the symbols related to the abstract concepts is demonstrated at this stage. Furthermore, children's abstract thinking patterns start to develop, where reasoning is executed purely by using symbols without the availability of perceptive data. A minor part of self-centred thinking returns early on in this stage.

Piaget's work on children's development has provided mathematics educators with crucial insights into how children learn mathematical concepts and ideas (Ojos, 2008). As mentioned previously there are correlations between the abstract thinking in Mathematics and OOP, and therefore the work of Piaget is relevant to this study.

2.3 Abstract Nature of Mathematics

Mathematics is applied in many disciplines such as Astrology, Engineering, Computer Programming and Theoretical Physics, to mention a few. According to Sinaceur (2014), "mathematical thinking ability" gives problem solvers even greater problem-solving abilities. Thus, Mathematics plays an important role in daily life, from the school benches to university lecture halls. In fact, many sources indicate that the ability to successfully comprehend and apply mathematical elements, such as the symbolic expression of relative values, numerical reasoning, cognitive computing, abstraction, generalization and formalization, does and can contribute towards extending the limited powers of the human mind (Armoni, 2013). Varma and Schwartz (2011) describe the process of learning mathematics as abstraction, i.e. taking perceptual-motor representation into richer and more abstract concepts. Furthermore, they point out that integers inherit natural or positive, zero and negative numbers, which are all abstract, a notion strongly supported by Sinaceur (2014).

Avraamidou and Monaghan (2009) suggest that the mathematical symbols, e.g. (+, -, x) which indicate addition, subtraction and multiplication can be grouped with other mathematical symbols as so-called mathematical abstract concepts. Sinaceur (2014) asserts that using symbols, such as “+” for addition, leads to greater mathematical abstraction as inherent properties and operations are assigned to these symbols within the mathematical context.

2.4 Tools Developed to Teach OOP

Various HEIs in South Africa (S.A.) and around the world are continuously searching for effective application tools to teach students OOP concepts. Over the years, various tools were developed for teaching OOP (Georgantaki & Retalis, 2007) and several kinds of tools and approaches purported to support OOP teaching and learning (Areias & Mendes, 2007).

Georgantaki and Retalis (2007), for example, developed “Karel the Robot” with the intent to introduce procedural programming, using the Pascal programming language. Subsequently, “Karel++” was developed to introduce students to the OOP era. Furthermore, Griffiths, Holland and Edwards (2007) designed a series of graphical micro-world tools concerning frogs and other amphibians. These micro-worlds allowed the visible actions and states of the amphibians to be controlled in two parallel ways: buttons and menus to send the amphibians messages, using a Java code pane.

At Carnegie Mellon University, a 3D Interactive Graphics Programming Environment (IGPE), Alice, was built. Essentially, Alice’s goal was to support the teaching of OOP concepts, facilitate the development of interesting 3D environments, and help novices explore new media for interactive 3D graphics (Al-Linjawi & Al-Nuaim, 2010). Another useful tool identified by Areias and Mendes (2007) is ProGuide, an educational tool used to support weaker students in problem-solving activities by encouraging them to answer questions that may help them reach a solution. The main idea was to support students' autonomous work by helping them find a solution to common programming problems.

Pittsburgh's School of Information Sciences developed QuizJET, a Java Evaluation Toolkit. This software tool, based on e-learning, guides students to the right directions at the right time as a skilful tutor does. The tool, using Java language, focuses on the basics of Object-oriented programming (Hsiao, Sosnovsky & Bruisilovsky, 2010).

For this study, it was important to investigate already existing tools aimed at improving students' ability to effectively apply OOP programming.

2.5 Tools Developed to Develop Abstract Thinking

Literature shows that many diverse tools have been developed internationally to support students, more especially first-year or novice students who encounter OOP for the first time as part of their studies. As the aim of this study is to develop a similar tool for South African students, the researcher studied the existing tools to determine their strengths and weaknesses.

In order to improve students' learning performance, Chen (2011) extended the application of the Pathfinder Network by designing a personalized system (PDRLS) to diagnose shortcomings in students' knowledge structures and provide follow-up remedial learning. As a result, Intelligent Tutoring Systems (ITSs) were designed to improve learning in real educational settings (Alen, Roll, McLaren & Koedinger, 2010). Alen et al. (2010) primarily focused on help-seeking ability within ITs, a type of software that provides detailed guidance to students as they learn a complex cognitive skill through problem-solving practice. This system embedded an automated method in the Geometry Cognitive Tutor to evaluate students' help-seeking behaviour. The software, intended to provide feedback on students' help-seeking behaviour, was called Help Tutor.

Another tool developed during the 1970's, Mini calculator, included not just digits but also increasingly advanced modes of performing calculations and representing outcomes, both in numbers and graphics (Saljo, 2010). According to Saljo (2010), this specific tool increased the capacity to externalize human cognitive functions, and thus had a positive impact on the learning abilities of students.

Maillot and Perrot (2012) used Nintendo Wii's gaming systems such as Wii Sports, Wii Fit and Mario & Sonic's Olympic game, because of their convenience for novice and older populations, their relevance to actual sport, and their ready availability in the marketplace of commercial software to maximize physiological challenge and increase physical activity. At the end of the program they found that practice did improve cognitive performance (Maillot and Perrot, 2012).

Mayo developed a multi-player interactive game, Story World Builder. This game tool was designed to motivate learners to improve their writing skills. The game requires learners to design and build a virtual place for their stories. Learners play an active role in the virtual environment as characters within the story. The program saves the transcript which students then use to write their stories (Xu, Park & Baek, 2011).

Several tools have also been developed in specialist areas such as psychology, psychiatry, psychometry, and neurology, to enhance the functioning of certain areas of the brain. Brain techniques such as transcranial direct current stimulation (tDCS) as well as transcranial magnetic stimulation (TMS) are examples of some of the tools. Hamilton, Messing and Chatterjee (2011) assert that these tools increase the performance of participants with various neurologic and psychiatric conditions. Of great importance amongst features of TMS, is their ability to penetrate the scalp and skull, using magnetic fields to induce a small current to depolarize neuronal membranes and generate action potentials. tDCS is arguably thought to control the resting membrane abilities of neurons (Hamilton et al., 2011).

Additionally, in view of the above, Chi and Snyder (2012) found that tDCS was able to aid more than 40% of participants in solving a nine-dot problem, which was given to test participants' abstract thinking abilities. The nine-dot problem required participants to connect nine dots with four lines, using either a pen or pencil on paper, without lifting either pen/pencil or retracing the line.

Additionally, Coolidge and Overmann (2012) found that numerosity, the ability to think and reason with numbers, greatly assisted with the development of the human cognitive ability for basic abstract thinking. Furthermore, the study indicated higher levels of abstract understanding and representation.

Researchers, Rute-Perez, Santiago-Ramajo, Hurtado, Rodriguez-Fortiz and Caracue (2014), discovered and further improved an open-software application, which they later called PESCO (Programa de EStimulacion COgnitiva in Spanish). This application includes exercises that train cognitive skills. Furthermore, the application performs a series of tests to assess the cognitive status of a person. To improve cognitive baseline ability, the application included: adaptation and motivation, different levels of difficulty, and support and encouragement (Rute-Perez et al., 2014) since it is important to stimulate, improve, and develop the part of the brain that is responsible for abstract thinking. Recent work by Oh, Chun, Lee and Kim (2014) re-iterates the fact that abstract thinking is a person's ability to think beyond the instant stimulus situation and the ability to categorize items and symbolic modes. Oh et al. (2014) see abstract thinking as the direct opposite of concrete thinking, in that, concrete thinking is thinking about objects as specific tangible items.

As previously mentioned, Rogerson and Scott (2010) assert that programming requires a high level of abstraction, and demands both practice and intensive effort. Abstraction is a mechanism that allows us to represent a complex reality in terms of a simplified model in order to suppress irrelevant details, to enhance comprehension (Hadar & Hadar, 2007). According to Kramer (2007), formal modelling and analysis have proven effective in terms of practicing and developing abstract thinking and consolidating the ability to apply abstraction. Understanding and analysing large, complex problems is made easy with the assistance of modelling - one of the most important techniques in Engineering. Moreover, Armoni (2013) strongly recommends the teaching of enough mathematics, formal modelling, and analysis since active learning areas such as OOP involve abstractions.

Music may also play an important role in brain functioning. Literature shows that music either aids or disrupts activities, e.g. working, studying, relaxing and leisure time (Gosha & Jairam, 2014). Gosha and Jairam (2014) are of the view that playing or listening to music could trigger happiness, sadness and even captivate surprise and excitement. Furthermore, music could also evoke emotions and assist students while they are studying or taking tests. As early as the 17th century, French scientist

Roger maintained that music had a calming effect on people in hysterical experiments, based on a study of his patients with mental disorders (Kalinowska & Kulak, 2010). Music might thus also assist students with improving abstract thinking.

This section described a wide variety of available tools that could improve the cognitive abilities of students. The following section will look at tools specifically available in the South African context.

2.6 Tools Development: A South African Perspective

Literature suggests that, compared to the international arena, not much has been done within the S.A. context to develop software tools that can assist students to stimulate their cognitive processes so as to enhance their abstract thinking abilities and facilitate their understanding of OOP.

It seems that many experts in S.A., especially in HEIs, concentrate on teaching programming language rather than on developing and implementing tools that can assist students with their academic performance. While Dehinbo (2011) sees the establishment of criteria to evaluate the use of web development platforms as important, Sanga and Venter (2009) argue that suitable software for a specific purpose is of utmost importance. Software needs to be considered and some criteria found to determine which application is more suitable for the purpose of learning and the needs of the students (Sanga & Venter, 2009). With that in mind, it becomes evident that there is a need for a software tool for South African students at UoTs to aid them with OOP. Such a tool should aim to enhance, improve and better the abstract thinking skills, and ultimate performance of students in OOP. For this tool to be effective, functions that will stimulate the part of the brain responsible for enhancing students' abstract thinking and cognitive abilities will have to be integrated (section 2.5).

2.7 Working Memory and General Discussions

Cognitive psychologist, B.F. Pennington, sees working memory as a "computational arena" in which information relevant to a particular task is maintained and subjected to further processing (Wolfe, 2001). Thus, working memory plays an important role in knowledge acquisition as the brain continuously receives sensory raw data before editing out data it deems useless. This is a continuous process, while the brain is sorting and supplying relevant data to the working memory. Upon receiving this data, the working memory then performs computational functions on it. In most cases, the working memory requests additional information, stored inside the long-term memory, in order to complete its processing on the information at hand and make sense of it.

There are extensive arguments in literature about whether general purpose cognitive processes, such as working memory, are only causally concerned with regard to mathematical development and/or the lack thereof. Many recent studies support the notion that working memory is related to/and important for mathematical performance (Raghubar, Barnes & Hecht, 2010). Although working memory has been linked to diverse skills such as mathematics and computer languages, it serves other purposes as well in that it can reliably predict reading comprehension and student performance (Shipstead, Redick and Engle, 2012) capacity too.

In summation, daily general cognitive processes overload the working memory, which then requires training to function at its full capacity (Klingberg, 2010). According to Klingberg (2010), so-called brain training can improve cognitive performance in a wide range of functions and this improved performance is associated with neuronal changes from the intracellular level to the functional organization of the cortex. Working memory needs to be exercised and trained to perform optimally at all times and handle daily workload pressures. In support of memory training, Klahr, Zimmerman and Jirout (2011) assert that pre-school training provides children with improved control of some mental processes, which are especially important to learning and understanding science and mathematics. Although many training exercises specific to working memory will not be discussed at length in this study, it is important to mention simple and complex span that increase the ability to remain attentive (Shipstead, Redick, & Engle, 2012).

Erickson, Hillman and Kramer (2015) assert that across all cognitive domains examined, subjects engaging in moderate intensity physical training activities result in enhanced cognitive functions. Working memory and the development thereof are very relevant to this study as the researcher's hypothesis holds that the development of abstract thinking ability will have a notable effect on the academic performance of students, especially delineated to OOP. As Raghubar, Barnes and Hecht (2010) also suggest a close relationship between working memory and abstract thinking ability, the researcher proposes to evaluate the development of working memory and the subsequent effects this development has on abstract thinking ability as an initial attempt to develop abstract thinking abilities.

2.8 Neuroplasticity

According to Perwej and Parwej (2012), neuroplasticity is a network of neurons in the human brain which consists of processing elements called neurons and coefficients (weights). These are bound to connections which constitute the neural structure responsible for the training and recall algorithms. Lamb, McKay, Thompson, Hamm, Waldie and Kirk (2014), and Acharya et al. (2012) maintain that neuroplasticity is the brain’s natural ability to function in response to our environmental learning experiences by forming new connections and altering its structure during the human lifespan. Similarly, literature shows that the brain can change itself physically and functionally in a number of ways at any age during the learning process. Regardless, there are limits to how much the brain can change which indicates that human abstract thinking abilities can only be stimulated up to a certain stage (Acharya et al. 2012).

Based on the recovery process of stroke patients, Pino, Pellegrino, Assenza, Capone, Ferrerri, Formica, Ranieri, Tombini, Ziemann, Rothwell and Lazzaro (2014) aver that neuroplasticity helps with the relearning of new patterns of activity by maximize the use of the remaining undamaged brain thereby increasing plasticity and aiding recovery and the ability to learn. Furthermore, Acharya et al. (2012) also discovered that harnessing the power of neuroplasticity can lead to people fully recovering from massive strokes and other head traumas, overcoming learning disabilities in a matter of months, rewiring obsessive-compulsive behaviour out of their brains, and restoring memory acuity and cognitive processing during old age.

The researcher believes that, if utilized properly in a well-developed software tool, neuroplasticity could help develop or stimulate the part of the brain responsible for abstract thinking. In turn, this may improve students, performance in dealing with concepts in OOP.

2.9 Decision Tree

A decision tree is a simple, though powerful, way of performing multiple variable analyses. Decision trees have the unique ability to supplement, complement, and substitute:

- traditional statistical forms of analysis (such as multiple linear regression);
- diverse data mining tools and techniques (such as neural networks); and
- recently developed multidimensional forms of reporting and analysis found in, for example, business, intelligence and public sectors (Jain & Srivastava, 2013).

An advantage of decision trees is their ability to find a strong relationship between input and target values in a group of observations that form part of a data set. Kwon Ji, Yoon Subin, Kim Cheryn, Kim Sang Ryul and Yoon Taeseon (2015) provide a good example of the use of a decision tree. In their research, they use the decision tree depicted in figure 2.1 to explain in detail a well-ordered list, which decides whether the players of any type of sports will play, or not, depending on the weather, of a particular day.

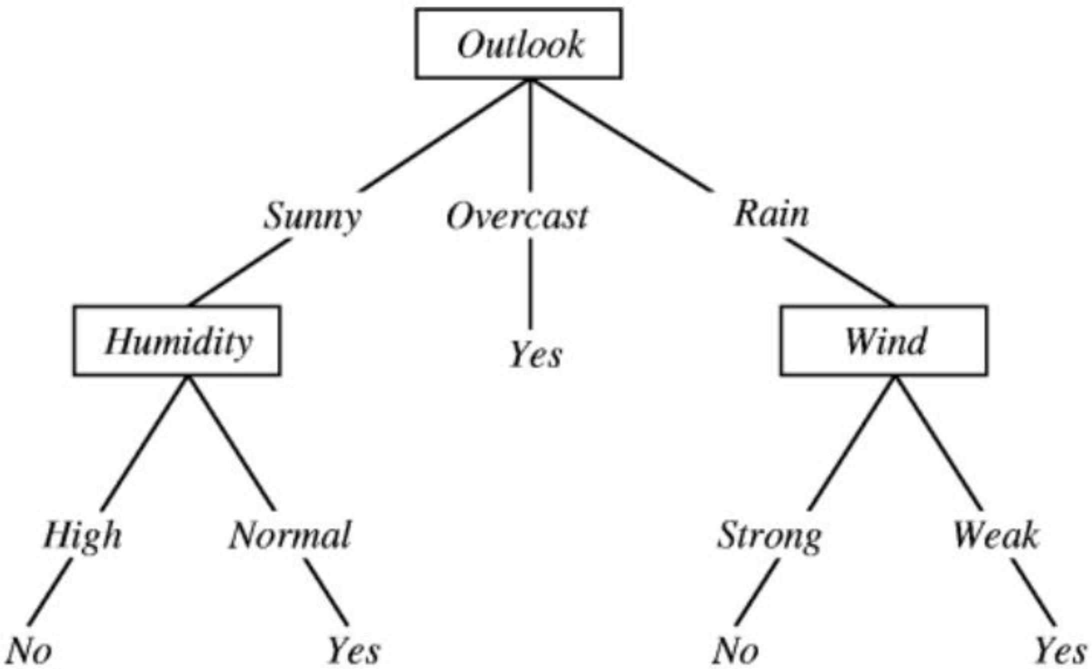

Figure 2.1: Simple decision tree (Kwon et al., 2015)

In an experiment, He Aixiang, Yu Jun, Wei Guangfen, Chen Yi, Wu Hao and Tang Zhenan (2016) used a decision tree to show a measurement circuit and testing chamber containing a micro hotplate-sensor array connected to a gas mixer controlled by mass flow controllers (MFCs). This complicated experiment could be explained clearly and logically because of the unique ability of decision trees.

Based on its remarkable structure with regard to data representation, the researcher regarded the decision tree, among others, as a suitable instrument of choice to logically outline, explain and demonstrate essential information in some parts of this study.

2.10 Chapter Conclusion

The objective of this chapter was to deliver a strong literature review pertaining the investigation in this study. Piaget's development theory was deliberated on in section 2.2; the abstract nature of mathematics was introduced in section 2.3; and the role of the tools developed to teach OOP was outlined in section 2.4. In the same light, tools to develop abstract thinking were delineated in section 2.5; a brief overview of tools available in the South African context was introduced in section 2.6. Section 2.7 outlined the importance of working memory with regard to abstract as well as computational thinking; and section 2.8 summarised the role and relevance of neuroplasticity inside the human brain. Finally, in section 2.9 the researcher provided a brief overview, from the literature, about the importance and usage of the decision tree with regard to data presentation.

In the following chapter, the researcher discusses the methodology employed in this study.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

Research comprises of scientific processes that are systematic and aimed at learning more about existing bodies of knowledge and pursuing new knowledge about humans, culture, society and many other areas of relevant interest. The ultimate aim is to develop and contribute to existing bodies of knowledge in a particular field (Salkind, 2009).

The successful acquisition and dissemination of new knowledge should benefit individuals and change their lives for the better by developing medical cures, methods to enhance teaching and learning, chemicals for sanitizing drinking water, for example, or by generating new strategies to address some cultural, societal or political issues. Salkind (2009) maintains that when undertaking research one should '*ask a question, identify important factors, formulate a hypothesis, collect relevant information, test the hypothesis, work with the hypothesis, reconsider the theory, and lastly, ask new questions'.*

3.2 Research Methodologies

Research methodology refers to more than merely the intended data collection methods related to an intended study. It encompasses scientific processes that lead researchers to understand which method, set of methods or best practices are best in particular situations (Peffers, Tuunanen, Rothenberger & Chatterjee, 2007).

Muijs (2004) holds that research methods in diverse fields of study often conform to two main categories, namely *qualitative* and *quantitative*.

3.2.1 Qualitative Research

Qualitative research focuses primarily on exploring phenomena about people or the environment in order to uncover or gain understanding of essential, non-numerical data such as motives, opinions and motivations. The ease of exploring the phenomena availed by the qualitative methods arises from a good correlation between the phenomena under investigation and the researcher (Taylor, Bogdan & DeVault, 2016).

Qualitative data collection methods make use of unstructured or semi-structured techniques. A few examples of common qualitative methods include, but are not limited to the following:

- Interviews: a conversation between two or more parties in which relevant questions are asked about a particular phenomenon and related answers are provided and recorded.

  The primary purpose for the researcher or research team to engage in interviews is to collect data because of the interviewer's interest in information about the participant(s) being interviewed, i.e. the interviewee(s). Interviewees may possess indigenous knowledge not readily available, unique perspectives, and/or could harbour certain feelings about certain subjects.

  The interview process can be conducted in various forms such as one-on-one, face-to-face, telephonically or through other forms of communication where participants are geographically separated. The interviewer poses questions, either pre-determined or improvised, to interviewees. In return, interviewees are generally expected, but not obliged, to provide answers.

  What makes the interview as a data collection method attractive and relevant, for and to certain situations, is that it affords the interviewer the opportunity to ask questions that are both structured (direct) and unstructured (open-ended) in order to gain valuable information from the interviewee (Preece, Rogers & Sharp, 2007).

- Focus groups: a data-gathering technique in which groups of people are asked questions about their opinions and perceptions regarding a service, concept or software intervention and so forth. Participants are encouraged to speak freely to other participants about relevant topics as they are usually in the same environment or share some or other commonality, whilst being scrutinized by the enquirer.

While Interviews are usually conducted on a one-on-one basis, focus groups involve interviewing groups of participants collectively, as a means of collecting relevant data. According to Moosa and Gibbs (2014), such data is usually required to better, enhance, change, or create a useful product and/or service targeted at a key group.

- Observations: observing people in their natural environment such as work-place, church, a community setting, etc. The aim is to understand and record the participants' reactions, interactions and perceptions within the realm of the perceived problem space. The research philosophy of *ontology* is associated with many studies in which observation was used to collect data. Ontology is concerned with determining whether the categories of *'being'* are fundamental to a study and the extent to which the items in these categories may be perceived to *'be'* or *'exist*' (Devaux & Lamanna, 2009).

  Observations afford one the opportunity to gain insights and provide a good understanding of, for example, how different participants behave while interacting with the newly developed intervention or service. Generally, a checklist is used during observation. This checklist could look at behavioral aspects such as the level of understanding or misunderstanding of the individuals observed in relation to the different parts of the product being scrutinized.

  Conversely, a major disadvantage of observations is that it is time consuming (Preece et al., 2007).

Mays and Pop (2000) maintain that qualitative research offers research methods that can, and do, enrich our knowledge and should not be seen as an easy option to execute or the route to a quick solution.

3.2.2 Quantitative Research

Muijs (2004) holds that the benefits of quantitative research can be exponential, as it can quantify the problem methodologically by way of generating numerical data. Subsequently, this data can be analysed using mathematical methods to transform it into valid, meaningful and useable statistics.

The quantitative data collection method is much more structured than its counterpart, the qualitative method. Some examples of quantitative methods are as follows:

- Surveys: unlike questionnaires, surveys are much broader data collection techniques used to collect and analyse data in order to learn more about things such as existing skills and knowledge, or to prove certain theories about participants (Olivier, 2004). However, questionnaires are commonly used in surveys to collect the relevant data.

- A questionnaire is an influential data-collecting instrument, consisting of open and closed-ended questions and used by researchers to collect large amounts of data from large groups of participants. A legitimate questionnaire is accompanied by a cover letter, addressed to the participants, outlining the importance of the study that is being conducted.

  There are different locations and environments from which a researcher may wish to collect data. Questionnaires allow flexibility as they permit the use of different approaches to present the questionnaire and collect data; from utilizing the pen and paper method to websites or telephone keypad vehicles.

  Results from questionnaires can be quantified, scrutinized and analysed objectively and scientifically in order to produce positive, valid and reliable information to test existing hypotheses.

  One disadvantage of questionnaires is that participants should be literate to engage the questionnaire successfully. Another is that the context and meaning of the respondent behind the response is not known to the researcher (Bowling, 2005; Preece et al., 2007; Salkind, 2009).

- Psychometrics: a field of study concerned with providing valid, reliable, objective, scientifically sound and legally acceptable forms of psychologically measuring skills and knowledge such as abilities, attitudes, aptitudes by differentiating cognitive abilities of examinees. Psychometric tests are usually presented in the form of a scientifically formulated questionnaire and are different from by other forms of questionnaires as they are usually universally scrutinized, standardized and accepted by the scientific community at large. Psychometric assessments have been deployed in other fields, e.g. industry, where employee assessment can improve performance, company culture and, importantly, attract preferred possible candidates for select positions. These assessments are integral to the data collection in this study since they can identify, amongst other things: personality, leadership potential, reasoning ability (verbal, numerical and abstract), learning potential and developmental gaps.

The General Scholastic Aptitude Test (GSAT) is an example of a psychometric assessment tool in South Africa and comprises sections of sub-tests developed to assess intelligence and aptitude. The average time it takes to administer the test is approximately two hours, taking into consideration the stoppages of time between each of the sub-tests in question (Claassen et al., 1987; Salthouse et al., 1989; Sturmey, 1994; Moely et al., 2002; Rust et al., 2009).

Muijs (2004) asserts that quantitative research is a preferred method when considering collecting numerical data to clarify a specific phenomenon.

3.2.3 Action Research

Action research is a disciplined process of enquiry initiated by individuals working together in teams in order to more effectively address, improve and solve real life concerns in an immediate problematic situation (Sagor, 2005). The premise on which action research is founded involves a cyclic reflective process of progressively solving a particular problem in either a participatory or a pragmatic fashion. The primary focus of action research is to identify a particular problem collectively and to develop and implement good strategies that can be applied practically in real-life problem-solving processes (O'Brein, 2001). According to Lindren et al. (2004) and Lowe (2007), action research is an interventionist tool employed to study technology or a particular phenomenon of interest by implementing and assessing change in a real-world environment.

Furthermore, Altrichter et al. (2008) assert that in order to improve and bring about positive change to an existing phenomenon, action research is used by bringing together various stakeholders such as students, psychologists and other advisors in a specific setting directly concerned with the phenomenon that is being studied. In the same light, researchers strongly focus on action research to better comprehend both the theoretical as well as practical knowledge with regard to the phenomenon under study (Lindren et al., 2004). According to Lowe (2007), action research is usually initiated by individual experts (teachers, lecturers, nurses, social workers, etc.), and for continuous sustainable improvements to the study, it is essential that all concerned participants be won over. Researchers are given a conducive platform from which to engage the work at hand in order to impart the knowledge and insights needed to eventually solve the existing problems.

Figure 3.2 depicts a simplified overview of the sequences of action-reflection cycles that represent the repeated nature of a typical action research process. Each cycle consists of the following important steps: **plan, act**, **observe** and **reflect** which are then followed by re-planning, action, observing and reflection. This process may be repeated by producing as many cycles as deemed necessary to complete the particular project or study (McNiff & Whitehead, 2002).

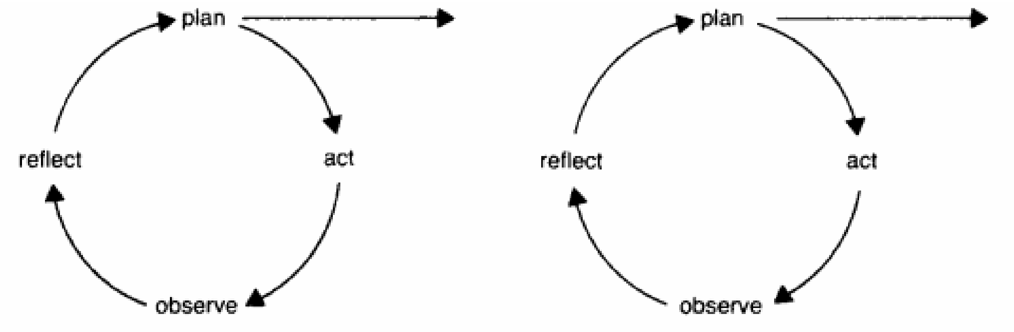

Figure 3.1: Sequences of action-reflection cycles (McNiff & Whitehead, 2002)

Since there are certain rules or principles to be adhered to when engaging in any form of activity, be it personal, social or scientific, action research is no exception. O'Brien (2001) lists the six essential principles related to action research as follows:

1. **Reflective critique**

   Reflective critique refers to participants' reflection on issues and processes related to a study while noting explicit interpretations, biases, assumptions and concerns upon which judgments are made.

2. **Dialectical critique**

Dialectical critique is a pre-requisite to understanding relationships amongst the elements and environment of the phenomenon.

3. **Collaborative Resource**

Participants in action research are regarded as co-researchers. The collaborative resource principle regards the ideas of everyone involved in the study as potential resources that are equally significant for creating interpretive categories of analysis negotiated by the participants.

4. **Risk**

This principle of action research is used to alleviate participants' fears regarding interpretations, ideas and judgments about them, and provides assurance that whatever the outcome of the study, their participation in the study is highly valued.

5. **Plural Structure**

The plural structure principle uses multiple possible actions and interpretations, preceded by a variety of views, commentaries as well as critiques communicated by parties involved in the particular study.

6. **Theory, Practice, Transformation**

In many occurrences, assumptions, theories and hypotheses determine the actions of people. With every observed result, theoretical knowledge is enhanced. Hence, continuous transformation is informed by theory, theory informs practice and practice refines theory from the view of the action researcher.

Other than qualitative or quantitative research which are single data collecting and analysing methods, action research is more of a collective approach to problem-solving (Altrichter et al., 2008). Thus, action research permits several different research tools or methods to be used as the study is carried out (Lowe, 2007). The methods, which are generally common to the qualitative research approach, include but are not limited to:

- keeping a research journal;
- documenting data collection and analysis;

- participant observation recordings; as well as
- structured and unstructured interviews.

Likewise, the general quantitative approach comprises of empirical tools like questionnaires, surveys, case studies, experiments, recordings, as well as participant psychometric assessment results (O'Brein, 2001; Lowe, 2007).

According to Lowe (2007), most action research methods are used in qualitative research as opposed to quantitative research methods.

3.2.3 Mixed Methods

According to Morgan (2007) and Creswell (2009), despite *the development and apparent validity of both qualitative and quantitative research in social and human sciences, mixed-method research has seen a combination of the two (quantitative and qualitative approaches) gain popularity over the decades*.

Furthermore, Creswell (2009), asserts that a combination of both qualitative and quantitative techniques provide a better understanding of a research problem than either research approach alone. Terrell (2012) maintains that the mixed-method approach can be a way to decrease the gap that arises in using either qualitative or quantitative approach exclusively.

Ivankova et al. (2006) elaborate on the strengths and weaknesses of the mixed-method approach as well as the importance and different order in which each method could occur:

- The Sequential Explanatory Strategy (SES) strongly focuses on collecting and analysing quantitative data first, then collecting and analysing qualitative data that can support and explain meaningless, numerical quantitative results.
- The Sequential Exploratory Strategy (SES) mainly advocates that the qualitative data collection and analysis of the explored phenomenon be supported by relevant quantitative results.
- The Concurrent Triangulation Strategy (CTS) primarily focuses on concurrently collecting and analysing data from both quantitative and

qualitative approaches to better corroborate, cross-validate and leading to reliable conclusions regarding a particular study.

According to Ivankova et al. (2007), the mixed-method approach, although relatively new, provide unique contributions to research and has been embraced by members of the scientific community in their research practices all over the world.

3.3 Research Activities

3.3.1 Interventions

As the ultimate aim was to develop an- and assess the impact of an IT intervention on the participants' abstract thinking and developmental progress during and after interaction with the intervention, two different groups from a pool of individuals that shared commonalities like age, field- and year of study were required for comparative purposes. One was the experimental group and the other the control group. Sampling was convenient in nature. Likewise, the intervention validated and recorded information derived from the participants for future measurement and analysis, in order to generate meaningful results.

The experimental group were observed during their interaction with the intervention, to gauge participant behaviour, reaction and understanding of the intervention's functionality and reliability. As such, notes were recorded in a research diary.

3.3.2 Case Study Applications

Case study is a strategy used by researchers to study a particular individual, group, event, and public or private organization within a specific place, setting or environment over a period of time. The purpose of such an endeavour is to understand and bring about change in the phenomenon being studied but may be limited by space.

A case study is an important and powerful tool that can teach researchers much about the enhanced or newly created phenomenon as well as the participants of that phenomenon by providing knowledge previously unknown to the researcher. With a case study, the researcher can study the phenomenon in the situation in which it occurs and produce tangible information about that phenomenon based on real outcomes and real stories, not just theories.

The advantage of a case study is that it yields valuable information of respectable quality (Olivier, 2004; Runeson, Host, Rainer & Regnell, 2012).

NOTE: Case studies can be employed as a data collection method in relation to both quantitative and qualitative methods and is used as an example of a quantitative data collection method for illustrative purposes here.

In this study a case study was useful with regard to the practical testing of the newly developed intervention in real-world settings. The intervention was installed successfully in one of the computer labs of the institution of higher learning in South Africa in a case study setting. The participants of the experimental group interacted with the intervention for approximately 28 weeks in the presence of the researcher. During the interaction sessions, the intervention also recorded certain quantitative usage and performance data, which will be discussed in more detail later in this discourse.

3.3.3 Experiment Applications

Experiments are often undertaken because the results generated inspire new hypotheses that necessitate even more investigation. Experimental research usually tests different assumptions of a specific phenomenon engineered by and developed under constructive conditions and measured by the researcher's work. Researchers or scientists ordinarily use this method within controlled settings until enough significant data is generated. Subsequently, the data from the experiment is recorded, measured, validated and analysed in order to arrive at a conclusion.

Independent two-group design with pretesting (ITDP), depicted in Figure 3.1, is an experiment design in the fields of Engineering and Information Technology, which gradually gained momentum in research and design over the years. The main focus of ITDP is to identify and select participants for a study and randomly divide them into two groups; a control and an experimental group.

Before starting the experiment, both groups are subjected to testing to assure that participants are comparable and to determine the groups' existing level of skills and knowledge relevant to the area or phenomenon under investigation (Olivier, 2004; Hinkelmann & Kempthorne, 2008).

Time	Experimental group	Control group
↓		
t_0	Randomly split into two groups	
t_1	Observe	Observe
t_2	Experiment	-
t_3	Observe	Observe

Figure 3.2: Independent two-group design with pretesting (ITDP) (Olivie, 2004)

3.3.4 GSAT and Questionnaire Applications

GSAT Psychometric evaluations were also done during the data collection phase of the study. This was done mainly to collect data about the existing abstract reasoning abilities (non-verbal) of all the participants of the study prior to the interaction with the intervention. The tests were repeated after the period of interaction to gauge the abstract reasoning abilities of both groups again and compare the findings.

Finally, a questionnaire was used to collect data from the experimental group participants, in order to determine their opinions and feelings of the functionalities of the intervention with which they had been interacting. The questionnaire (see Appendix B) contained both open and closed-ended questions.

Although there were two cycles to the design of the intervention, the researcher is not convinced that the study, at large, can be defined in terms of action-research. However, an action-research approach may be the foundation of a future study.

3.4 Ethics

Ethics refer to the well-founded standards that distinguish between good and bad, or right and wrong in relation to the actions, rights, obligations, decisions, characters and specific qualities of human beings (Rampages.us, 2016). In short, ethics are the basic concepts and fundamental principles that lead to the accepted norms, values and informal rules at the heart of all human interactions (Scholarship.richmond.edu, 2016). Ethics, therefore, primarily strongly focus on justifying doing good and avoiding doing harm to humankind at all cost (Aluwihare-Samaranayake, 2012).

According to Rothstein (2015), individuals have an ethical obligation to participate in research for the improvement of all humankind. However, it remains the individual's right whether to participate in research or not (Johnson, 2014).

Aluwihare-Samaranayake (2012), Johnson (2014), and Özcan and Balcı (2016), assert that the following is essential before any kind of research project that involves human participants under the support of a particular institution could commence:

- Obtaining ethics clearance and approval for the research project from the local institution where the study is undertaken to collect data collection for local design sessions.
- Conducting preparation sessions, prior to the design sessions, to inform and educate participants about the study context.
- Obtaining relevant representatives' involvement and agree on terms of reference for participation.
- Preparing relevant information consent forms.
- Conducting information consent sessions with the potential participants to introduce them to the research project.
- Administrating and distributing post-study data.

Prior to the commencement of the research, it is imperative that both the participant and researcher reach a mutual agreement through an informed voluntary consent form. A consent form is an important document, willingly signed by a participant. This form confirms that a participant understands and agrees with the terms and conditions stipulated in it, with regard to the study undertaken (Johnson, 2014; Nejm.org, 2016).

Rothstein (2015) asserts that some bioethics scholars and researchers find informed consent too burdensome, expensive, unreasonable, long, and argue that it does not work or have paybacks. However, with good planning and a perfect design, the development of a simple, inexpensive, short, positive, and general measure of informed consent form, would definitely have several important benefits for the study (Joffe et al., 2001). For the consent form to accomplish the ethics' main objective

Joffe et al. (2001), Rubinstein et al. (2014), and Nottingham.ac.uk (2016), list a few requirements a reseacher can choose from:

- Providing information as well as contact details about the researcher;
- Providing the details about the research project;
- Describing what will be required of the participants, including amongst others, the amount of time required of participants;
- Explaining that the participation is voluntary and that they have a right to opt out of the research;
- Ensuring participants that confidentiality is guaranteed with regard to any provided information;
- Assuring participants that anonymity is also guaranteed, no information provided will be linked back to the participants;
- Informing participants about any potential risks as well as harms that might occur;
- Informing participants about potential benefits with regard to participation in the study;
- Ensuring participants that feedback or results will be made available on reasonable request; and
- Providing enough space for the signature of the agreeing participant and the date.

According to Rothstein (2015), *the informed consent document is the researcher's personal pledge to honor and, in good faith, adhere to the ethical conduct approved by an institutional review board (IRB), which represents the shared morality of the community*.

The students that partook in this study gave written consent to participate in this study after a deliberation between the researcher and the students and a review of their rights as participants. These rights and what was expected of them as participants were also relayed to the participants in writing. The exam department of the relevant university also provided ethical clearance needed to proceed on the trajectory set out for this project.

The researcher first deliberated on the study's general processes and participants relevant to the study. The main topic of the study followed and participants were informed that:

(1) they had the right to withdraw from the study at any time, if they felt uncomfortable about continuing;

(2) their confidentiality and anonymity regarding participation in the study was guaranteed;

(3) the results or feedback, including a copy of the completed research report, would be made available to any participant upon reasonable request;

(4) the researcher did not foresee any possible harm to the participants; and finally

(5) participants were asked to contact the researcher at any time, on the contact details provided on the consent form.

3.5 Chapter Conclusion

This chapter reviewed and discussed research methodologies and related empirical data collection methods, explaining qualitative, quantitative and mixed approaches. For completeness, a limited discussion on action research was also included.

A section was also dedicated to discuss case study and experiments. Experiments were envisaged and ultimately employed to assess the theory stated in this discussion in an attempt to answer the research questions posed in section 1.3 of chapter one.

All ethical issues necessary for the data collection processes were also observed and the participants and the exam department of the university related to this study provided the required consent.

The researcher used a mixed approach to conduct the research and employed an experimental approach.

Chapter 4 focuses on reviewing the study, the intervention as well as data collection process.

CHAPTER 4

INTERVENTION DEVELOPMENT AND DATA COLLECTION PROCESS

4.1 Introduction

Extraordinary works of art, Mathematics and Physical Science are but a few examples of what is possible with the human ability to think and relate to objects in an abstract fashion. Abstract thinking ability, or abstract reasoning ability is a key role player in the ability to solve problems, innovate and be creative (Lister, 2011).

From an educational perspective, subjects like Mathematics and Physical Science have been linked to abstract reasoning. There are many arguments with regard to Basic Education and Training and whether it is doing enough to produce fresh thinking leaders in the fields of Mathematics, Science and Engineering. This is especially true in the South African context where the scarce skills pool includes professions like Engineers, Scientists and Science Technologists, Doctors and Nurses as well as Computer Professionals. The named professions all require elements of strong problem-solving abilities and creativity that, in turn, can be traced back to above average abstract thinking abilities in individuals who excel in these fields (Daniels, 2007).

The ability to think abstractly may impact academic performance, negatively or positively, in the subjects mentioned in the preceding paragraphs. By this, the researcher is not implying that the abstract reasoning ability (or lack thereof) of an individual is the sole contributing factor to academic performance and realizes that environmental, social and emotional factors, amongst others, can also play a pivotal role in academic performance. Rather, the study seeks to explore the link, if any, between abstract reasoning ability and academic performance in a subject that is abstract in nature and how, if at all, an IT intervention that stimulates abstract reasoning will influence said performance.

Primarily, the researcher chose the OOP module for this study because of its abstract nature. A secondary motivation for choosing this module is the fact that the researcher has observed that tertiary students who encounter the module and its content for the first time tend to struggle with it. To support the notion that abstract thinking indeed does have a measureable effect on the academic performance of an individual in OOP, and in an attempt to negate the role of other academic performance inhibiting factors mentioned earlier in this section, the researcher also considered other modules in the curriculum of the relevant university program. These other subjects, in turn, were selected because of the assumption that they do not require creative problem-solving but rather depend on the brain's ability to recall and recognize the content that was studied. In short, this study considered and compared the average performance of students in modules that are less inclined to require abstract thinking abilities with those of subjects that do require abstract thinking abilities from the student. An example of the latter is a module named IT Mathematics, which has been included for comparison.

Although this study may hint at the abstract thinking abilities of students and the relationship between this ability and academic performance in relevant subjects by comparing the academic results of different modules that require different cognitive abilities, it does not provide hard, scientifically sourced evidence needed to stand up to rigorous methodological scrutiny. A method to accurately and scientifically gauge abstract reasoning abilities is therefore necessary.

Assessing the abstract thinking ability of a particular person scientifically may seem challenging, and, in many ways, it is. Fortunately, the field of psychology offers some attainable solutions toward that end in the form of psychometric evaluations. One of the solutions that the researcher has employed to assess the abstract thinking abilities of the participants is a psychometric test, the General Scholastic Aptitude Test, or GSAT, discussed later in this chapter.

Literature confirms that many different software tools have been developed to support the stimulation and support of various cognitive processes. However, few of the investigated IT instruments encountered in the literature were developed to address abstract reasoning ability, especially in the context of OOP and the academic performance of first-year students at Universities of Technology (UOTs) in South Africa.

4.2 Identifying Abstract Thinking Ability in Individuals

According to the psychologist involved in this study, the level of abstract thinking that an individual has can relate to the individual's ability to classify objects, for example pen and paper and how they relate to each other. An acceptable classification might be that these items are stationery. Constituents of abstract reasoning ability include the ability to explain the functionality of objects as well as describe objects from memory as the individual perceived them. In Bloom's Taxonomy, the ability to classify objects is one of the highest cognitive levels, namely *analysis*.

Forehand (2012) explains analysis as the ability to break up and classify different objects into basic parts with the aim of determining how the parts relate to one another and to conceptually assign an overall structure, or purpose, to the objects through differentiating, organizing, and attributing the related parts. Working memory is largely responsible for the brain's analytical processing function (Shipstead, Redick & Engle, 2012).

Using the same example of the pen and paper: an individual may exhibit different levels of abstract reasoning by explaining the functionality of both the objects in relation to each other. In this regard, an acceptable answer may be something like an explanation of what pen and paper can be used for together, suggesting that a pen without paper has less potential or vice versa or by executing/implementing an example of the above mentioned. According to Forehand (2012), the ability to explain the functionality of an object is on the lower level of Bloom's Taxonomy.

Finally, on the lower levels of Bloom's taxonomy, the ability to relate a physical description of an object or objects from memory can also form part of abstract reasoning ability. For example, the description of a pen may be something like the fact that a pen is orange in colour, has a blue cap and that it is made of plastic. The description of the paper could be about its texture and that it is white. The process of describing the perceived physical objects is referred to as *concrete* description, and includes the brain's ability to understand information derived from the senses in different formats. This ability helps humans to construct meaning from oral, written and graphic messages through interpreting, exemplifying, summarizing, inferring, comparing, and explaining (Hadar & Hadar, 2007).

Based on the information presented in the preceding sections one can assume that when gauging abstract reasoning abilities, the tool one employs should assess all three of the named brain functions. Furthermore, if one attempts to design and implement an intervention to stimulate and enhance abstract reasoning abilities, all three of these functions should be stimulated whilst simultaneously employing and stimulating the brain's plasticity. Klingberg (2010) affirms that the improvement of working memory and other cognitive functions such as brain plasticity can be achieved through training. Thus, if trained and stimulated with the right tool or instrument, the right content and in the right way, the brain can form new pathways and build new connections through its inherent neuroplasticity. The improvement related to the abstract thinking performance of an individual can be long lasting, even permanent if the stimulating content and related instrument pushed the brain to make neural changes in the intraparietal-prefrontal network through the repeated execution of particular tasks that stimulate particular sections of the brain or by triggering certain thinking mechanisms (Klingberg, 2010).

4.3 Initiating the Study

The researcher initiated the investigation with a meeting to recruit available first time first-year IT students from a University of Technology in South Africa.

The aim and purpose of the study were outlined during the meeting and all willing prospective participants were informed about all ethical aspects related to the work as well as the rules of participation. All prospective participants were informed of their right to withdraw from the participation of this study at any time if the relevant participant felt uncomfortable with the completion of the study in any way, their right to provisionally request copies of the data collected as well as the final analytical information and the interpretation thereof. Prospective participants were also informed of the psychometric test that each one of them was expected to undertake as part of the study, the need thereof and so forth.

After the initial meeting with the group of possible participants, the researcher approached available experts in the field of psychology who were shortlisted based on their experience with psychometric evaluation. Several one-on-one interviews were held with those psychologists who had the relevant background and were willing to assist in this study. One psychologist was eventually selected and contracted.

A follow-up meeting was held with the possible participants, and with the help and under the supervision of the employed psychologist, the envisaged aim and outcomes of the study as well as the tools that the researcher aimed to utilize, including the GSAT, were explained. A pool of voluntary participants was identified and, from it, participants were randomly assigned to different groups.

4.4 The General Scholastic Aptitude Test (GSAT)

GSAT was developed to revise and improve upon previous intelligence and aptitude tests used in South Africa. In general, GSAT assesses the general scholastic aptitude of South African learners and is divided into three overlapping levels namely Junior, Intermediate and Senior. Norms are provided for non-verbal, verbal and total scores in each assessment. Norms were developed for:

- the combination of English and Afrikaans-speaking learners; and
- the non-environmentally disadvantaged.
- Age norms: Norm scores have a mean of 100 and a standard deviation of 15 (IQ scale). Stanines and percentiles are also given.
- Standard norms: Standard groups serve as reference groups. Norm scores have a mean of 50 and a standard deviation of 10 (Claassen et al., 1987).

A standard GSAT also assesses, amongst other things, the non-verbal and thinking skills of the person being assessed. According to Jenkings and Sibaya (2004), these skills are directly related to the abstract thinking abilities of the person. Therefore, a standard GSAT assessment formed part of the research evaluation to assess both the non-verbal as well as the verbal skills of the control and the experimental group. Using the psychometric lens, the researcher ultimately aimed to quantify the abstract thinking abilities of the participants of this study.

Since, according to La Rue (2010), nutrition plays a role in cognitive performance and the brain takes approximately 90 minutes from the time an individual wakes up to reach optimal functioning capacity, all participants were supplied with a small but nutritious snack before engaging in any assessment and/or the developed intervention (for the experimental group). All engagement sessions were also scheduled during the mid-mornings throughout the duration of the study, in an attempt to negate/limit the impact of the participants' cognitive processes not operating at near acceptable capacity.

4.5 The Participant Profile

Ultimately, 111 participants were selected, availed themselves for the assessment process, and signed the relevant consent forms. Three groups of 37 randomly assigned participants were formed, one the control group and the other two experimental. The participants were 108 traditional Africans, 2 Caucasians and 1 mixed-race participant. Figure 4.1 depicts the racial profile of the participants.

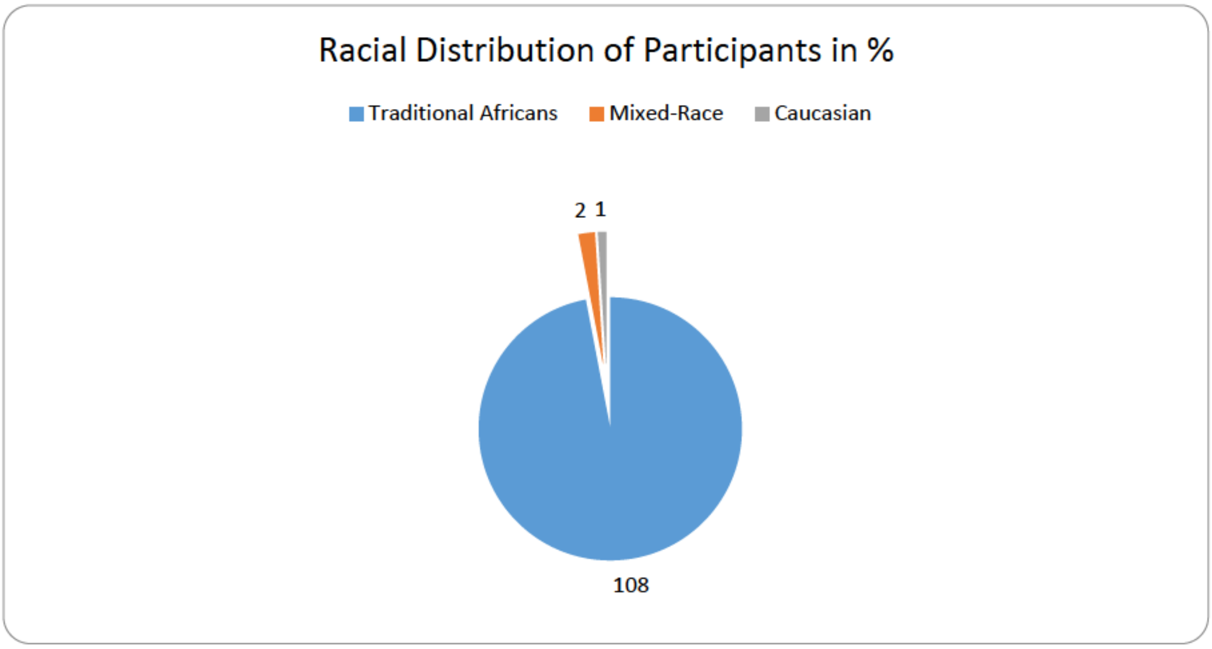

Figure 4.1: The racial distribution of the participant group

Table 4.1 provides an overview of both the age range and total number of participants per age group, expressed as a percentage. The total number of participants had an age distribution as follows:

- 47% of candidates were from twenty to twenty-two years of age;
- 28% of the candidates were eighteen to nineteen years of age; and
- 25% of candidates were greater than or equal to twenty-three years of age.

Age Range	Percentage of Total Sample
Range of >= 23	25%
Range of 20 - 22	47%
Range of 18 - 19	28%

Table 4.1: Age overview of participants

The gender statistics, relevant to the group as a whole, were also recorded and are available for perusal in Appendix E, but was not considered as an impacting factor in the study.

4.6 The Control Group

The control group consisted of 37 voluntary first-year IT student participants from a University of Technology in South Africa. This group underwent the pre-test and the results obtained to establish a baseline result for later comparison.

The control group, not allowed to interact with the intervention, were tested again after 8 months, during which time the experimental group(s) was/were exposed to the intervention and interacted with it. The standard related to psychometric testing suggests that there be a period of at least 6 months between specific psychometric testing (Claassen, du Toit, Hoffman & Vosloo, 1987).

The post-test results were used to establish a baseline result for comparative purposes.

4.7 The Experimental Group

There were two experimental groups of 37 voluntary first-year IT student participants each. The reason for two groups was purely logistical in nature, as the laboratories in which the groups engaged the intervention had a maximum capacity of 40. The choice to have a larger experimental group was made on the notion of collecting a larger pool of related data. A larger pool of experimental group data would arguably allow for richer data, allow for elaborate analysis of the data and provide a greater foundation for any claims made based on the analysed data. The experimental group were subjected to both the pre and post-tests on the same day as the control group. The pre-test data was collected and scrutinized and formed part of the baseline result.

The experimental group engaged the intervention four times a week for an hour at a time for 7 months, in a controlled computer laboratory environment. A period of 7 months was decided upon because, according to Bezzola et al. (2012), it takes approximately 66 days for new neural connections and associations to be formed and to become permanent. These new connections are variably reinforced if stimulated over a further 60 to 90 days. It therefore takes approximately 5 months of repetitive stimulation for new neural connections and associations to form and establish permanent links/paths. Another 2 months of intervention usage were added to accommodate assessment and holiday periods related to the relevant tertiary institution. It was anticipated that the participants may spend less than the envisaged four hours a week engaging the intervention during the relevant assessment and holiday periods.

The post-test data was collected and scrutinized so that the different sets of data, namely the pre-test data of both the control and experimental groups as well as the post-test data of these groups, could be analysed comparatively. The researcher was especially interested to see what, if any, difference there would be in the post-test data of the control group and that of the experimental group as the control group was not exposed to the intervention at all for the duration of the study, as opposed to the experimental group.

4.8 The Pre and Post-Test Layout and Content

The reasoning behind conducting a pre-test was to extrapolate the abstract thinking ability and academic performance related to OOP of the participants in a scientific, known and recognized manner before any interaction between the participants and the proposed intervention occurred. All participants, i.e. both groups, took the pre-assessment before any interaction with the intervention. Both participant groups took the post-test after the intervention interaction period.

The pre-test therefore entailed two sections, namely the standard GSAT assessment and a secondary section that related to OOP. This section was developed by the researcher to indirectly cover basic OOP concepts. The aim of including this section in the assessment was to extract the participants' indirect performance and compare the results, irrespective of their previous academic performance in these areas.

The registered psychologist with the relevant skills in the field of psychometrics was employed to administer both sections of the pre-test to all of the participants with the aim to gauge the abstract thinking ability of the participants. The same psychologist was also responsible for the subsequent analysis of the related GSAT data. The tests lasted approximately 3 hours, respectively.

After being presented with the results of the pre-test, the researcher was able to gain some initial insight into the participants' abstract thinking abilities and the possible link between abstract thinking abilities and academic performance in OOP. This was done by comparing the scores obtained for the OOP-based sections of the pre-test with the scores related to the abstract thinking GSAT section of the assessment.

4.9 Considering Structured Programming Performance

To form a complete view of student performance regarding the programming paradigms of OOP and structured/procedural programming, student performance figures relating to both groups were needed. Comparing and presenting student performance in each of the mentioned programming paradigms would be both interesting and valuable, especially as structured/procedural programming is comparatively much less abstract, though not completely absolved of basic abstract concepts, in nature than OOP.

At the time this study commenced and at the respective times that the pre and post-test were administered, none of the students that participated in this study and made up the relevant control and experimental groups were exposed to the OOP programming paradigm yet. The content of the programming module presented at the tertiary institution only covered structured/procedural programming during the first semester of the first year of study. Fortunately, the pre and post-test provisionally provided a section in which the questions presented, indirectly, covered and assessed OOP concepts. In turn, the analysis of the particular section would provide insight into the participants' OOP-related performance.

The semester examination paper of the programming module at the tertiary institution provided a good source of data from which to assess and gauge the performance of students with regard to structured programming, as the relevant examination paper largely covered structured programming in the questions presented. The quarterly tests that the students wrote covered the structured programming material of the module provided, yet another data source from which data regarding student performance in structured programming could be extrapolated.

The comparative data between student performance in structured programming and OOP is presented in the next chapter.

4.10 The Intervention

One of the aims of this study was to design, develop and implement an IT instrument that stimulated the abstract thinking ability of its user to the end that the abstract thinking ability of its user was affected positively. The study also wanted to investigate what the constituents of such an intervention should be to reach the proposed goals. This could only be done through trial and error; by designing and testing an intervention, analysing and interpreting the results scientifically, and going back to the proverbial drawing board if it was necessary, only to repeat the process again.

4.10.1 Intervention and Core Components Overview

The first iteration of the proposed IT tool was made available as a desktop version only. The intervention was deployed and available on computer laboratory machines in a computer laboratory of a University of Technology in South Africa and nowhere else for the duration of the study. This measure helped to ensure that interaction with the intervention occurred under controlled conditions in a controlled environment. Furthermore, this measure also helped to ensure the integrity of the resultant data, collected from the participating subjects. Other measures to ensure data integrity were also put in place and will be discussed in the subsequent discourse.

Dedicated code modules as well as a dedicated repository for warm-up games and exercises were developed, which will be discussed in more detail in a subsequent section of this discourse. More importantly, the intervention also consists of and incorporates a subset of game-driven exercises and questions that target the psychometric and working memory of the participants. These games, exercises, and questions were based, in part, on the principles and science behind the GSATs.

Each subset of games, exercises, and questions grew in complexity and were constructed from a repository that responded to a code module created with the purpose of generating random scenarios from the content of the repository. This measure helped to ensure that unique scenarios with regard to the exercises were created. This approach was utilized with the aim to keep the working memory process of each participant working hard as opposed to relying on long-term memory to solve exercises that would otherwise be repeated with the same content.

The intervention also incorporated an amendment of the ideas proposed by Griffiths et al. (2007) in their research, combining those ideas with amended elements of the work put forward by Areias and Mendes (2007). As mentioned in the previous paragraph, the third component added to and incorporated the game-based exercises features that were uniquely developed to include psychometrically based content and objectives that could only be reached through the completion of different sections of different games. All of the content was developed specifically with the aim to activate the cognitive processes of working memory.

Each participant logs in with his/her supplied participant number, the intervention then logs all answers per participant as well as keep a log of how related exercises were constructed. This was done to identify specific areas where respondents were struggling by making use of a code module that did the following:

- Identified each participant’s answers and created a participant specific dynamic profile of shortcomings in terms of the type of section of a particular game/particular exercise or question with which the particular participant struggled.
- Constructed content iteratively and in growing complexity from the repository related to the area in which the particular participant had trouble.
- Tracked, logged and reported on participant performance.

- Activated a new level of interaction based on the successful completion of lower levels. The levels built on one another and for each subsequent higher level to be activated, the relevant participant had to have successfully completed all preceding levels, much like a modern video game.

When the different participants initiated the application, a code module identified the user according to his/her user number. A different module then made use of the identification to load the user profile in terms of progress and level of interaction to date from a dedicated log file. Each time the intervention was used by a specific participant, the application customized the sections of games and questions iteratively to a (limited) degree over the period it was used by the particular participant. The newly created content contained the same elements and composition as that of the identified areas where below average performance was recorded, but not the same content as to minimize the effect on and use of long-term memory to complete the exercises. This was done to provide maximum working - memory stimulation for each participant with each use of the application.

The process of changing and adapting the sections of games and questions of the intervention was limited in scope, as the repository of content for the different games and sections of games was limited, as was the capacity of the intervention to analyse and adapt to the participant profile beyond established parameters.

The information logged regarding participant performance was not made available to the participants, though they were made aware that the intervention was collecting data related to usage and performance. Only a handful of people related to this study and the documentation thereof had access to this particular data.

Three-tier architecture was employed with respect to the development process, as described by Grozev and Buyya (2013). This architecture was used to ensure the proper and successful construction, testing and maintenance of the software application. Figure 4.2 depicts the sequence in which the 3-tier architecture was implemented.

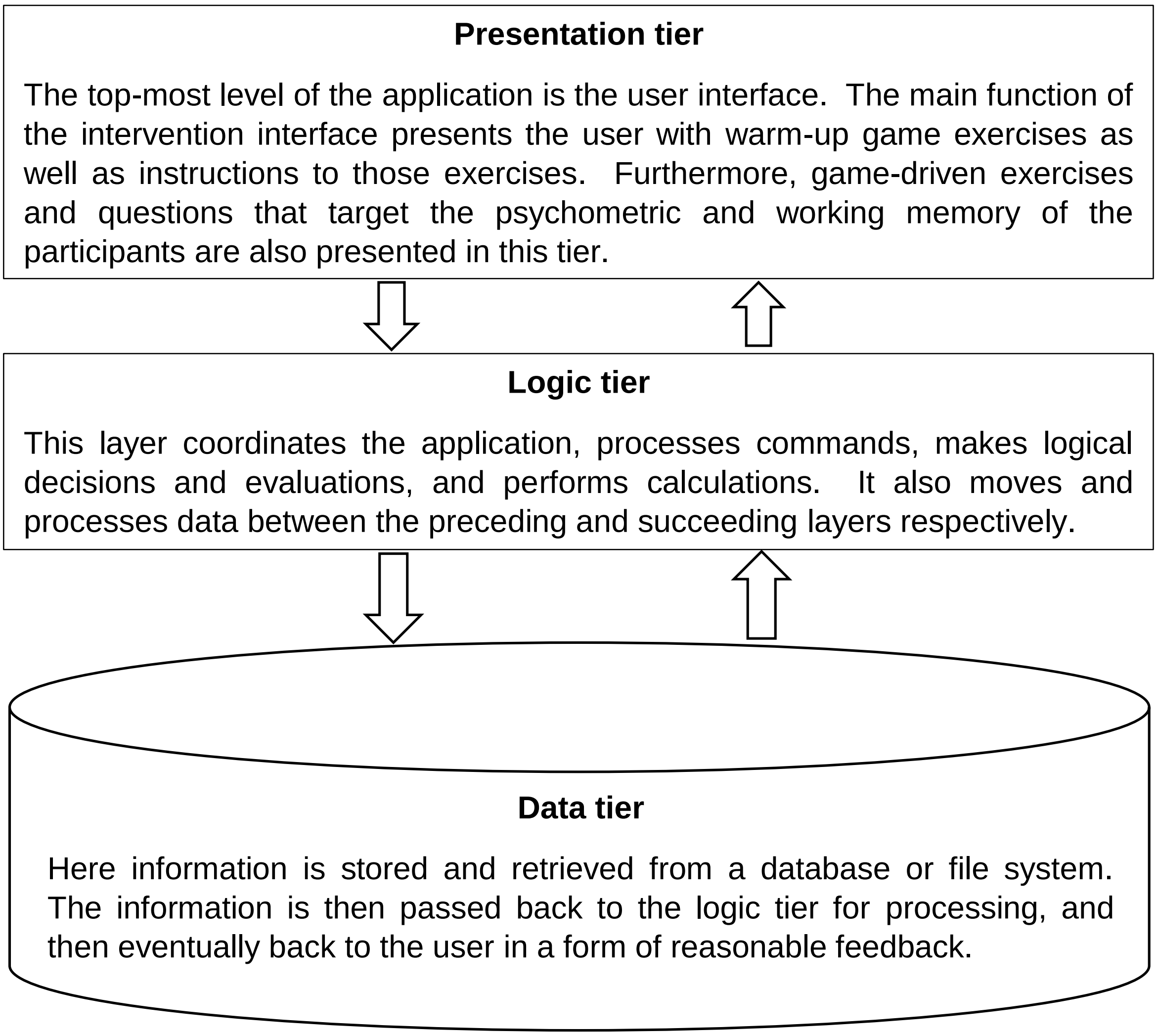

Figure 4.2: The 3-tier application architecture as adapted from Bageri (2013)

The results anticipated from the cognitive stimulation of the application of the incorporated methodology relevant to abstract reasoning were an indication of the development of abstract thinking abilities in the users thereof. This cognitive stimulation, in turn, may have enhanced students' performance with regard to the comprehension of OOP concepts and their academic performance.

When the application is launched, the user, whoever he or she may be, will be met with the login screen, as depicted in Figure 4.3. Users with different profiles and privileges use their relevant login credentials to gain access to different functional areas of the application. The information tab was developed and implemented to act as a central communication point from which the researcher could communicate important information to users without the need to contact every user personally.

The admin tab may be deemed unnecessary, but provides a dedicated login platform for the administrator, as does the user tab. Only the administrator is allowed to add or remove users as well as amend certain functional aspects of the application and view the data collected by the application relevant to general use or related to a particular user or set of users. The necessary precautions and safeguards with regard to assessing and validating user credentials were incorporated in a code module that is used by the login section of the application to protect access to the application as well as provide a layer of security with regard to the data collected by the application. The login section also records which user has logged in and communicates this information to a separate code module. This module uses the login information to identify the user profile as captured by the application with the aim to provide a customized set of games, exercises, and questions based on the user's performance up to the time he or she logs in, as mentioned earlier in this section.

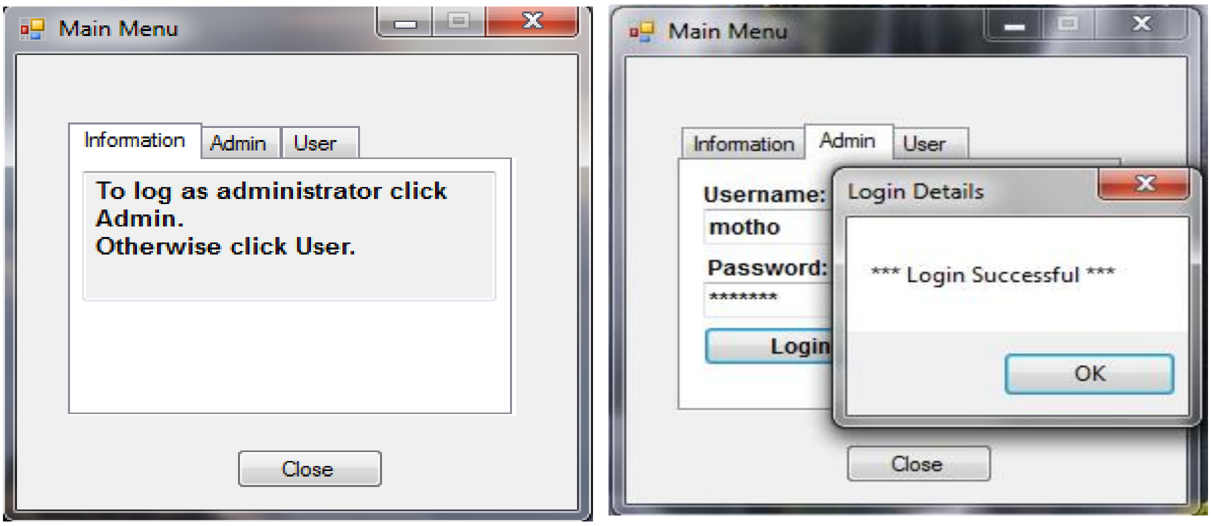

Figure 4.3: Main screen for the intervention

Figure 4.4 shows an excerpt of data that was collected by the application and to which the administrator has access. From the depicted screen, the administrator is also able to engage a subset of functional aspects of the application, such as organizing the data, or viewing certain data on request.

The options available in this section of the application allow the administrator the following:

- Dots: Used to display previously stored data regarding the nine dots connection workout. The data can be requested for a specific user, a specific subset of users or all users for stipulated sessions.
- Exercises: Used to display previously stored data with regard to the different types of abstract reasoning workouts. The data can be requested for a particular user, a specified subset of users or for all users related to the most recent interaction session.
- Randomized: Used to explicitly re-shuffle the repository of content according to specified sections or of all the sections.
- Users: Provides more functionality than the "Exercises" option. This option is utilised to display stored data specific to specified sections and specified sessions for specified users of the application. Different combinations of parameters can be set for data related to the different sections of the application, different interaction sessions as well as for an individual user, a subset of users, or all registered users of the application.
- Print Dots Report: Used to produce hardcopies of the nine dots connection report based on specified parameters.
- Print Exercises Report: Used to produce hardcopies of the various abstract reasoning workouts reports based on specified parameters.
- User: Used to enable and disable workouts relevant to specified users or all users and to manipulate user credentials.
- Close: Provides a record of everything the administrator did during the current session, including the administrator's login details, to a log table and closes the current session.

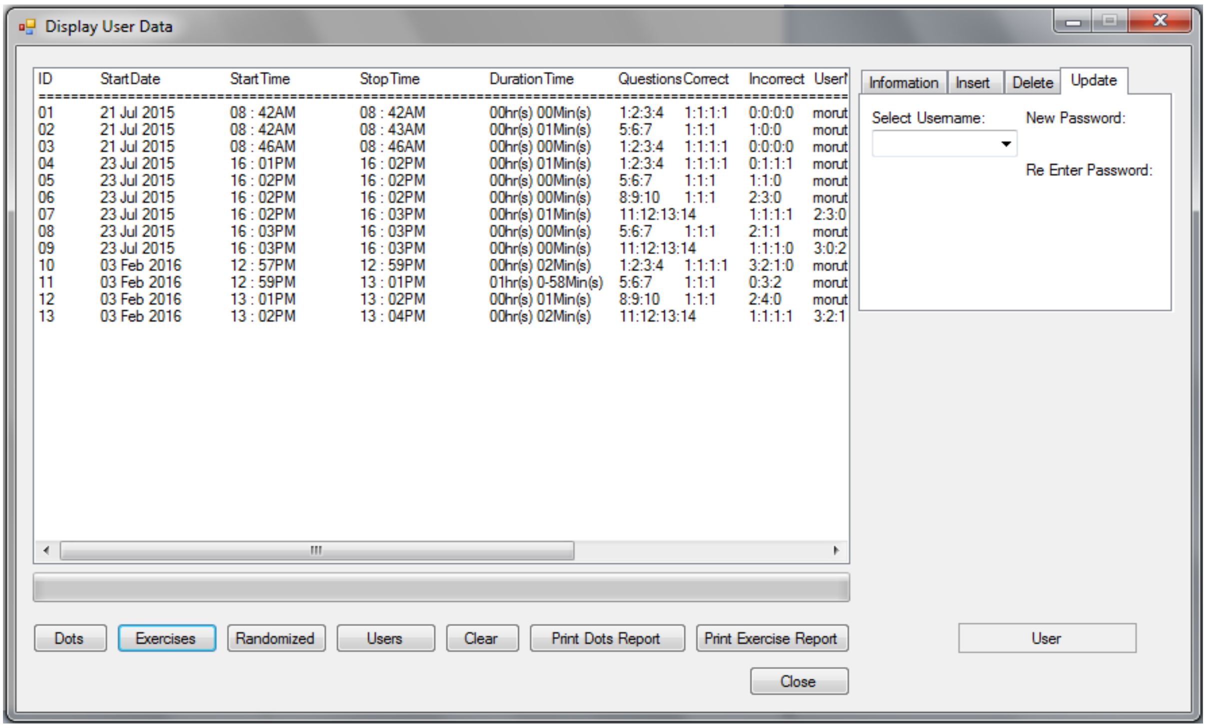

Figure 4.4: An snippet of the administrator interface section

An excerpt of the SwitchBoard code module, considered to be the backbone of the intervention in many respects, is depicted in Figure 4.5. The major functionality of this code module is to integrate an array of secondary concurrent code modules running in different processing threads. These secondary modules contain the vital psychometric mechanisms that form the primary constituents of the entire intervention. The exhibited section of code performs the following functions:

- The code disables all the SwitchBoard code module workout buttons, except workout number one's button. Workout number one's button is automatically enabled by this code, to allow the user full access to this workout's code module.
- Workout number two's button is automatically enabled upon the user's completion and closing of workout number one, which then again disables workout number one's button.
- Workout number three's button is automatically enabled upon the user's completion and closing of the second workout, which subsequently leads to the disabling of workout number two's button. This process continues until

workouts number four and five have been enabled and disabled, respectively, based on these principles.

```
if (exercise is frmDrawPoints)
{
    CountDots++;
    //test if countdots is more than 1
    if (CountDots > 1)
    {
       //Ask user to make a choice
       if (MessageBox.Show("Do you want to re-take this exercise?", "Retaking
       Exercise Message", MessageBoxButtons.YesNo, MessageBoxIcon.Question) ==
       System.Windows.Forms.DialogResult.Yes)
       {
          MessageBox.Show("WELCOME TO THIS EXERCISE!", "Welcome");
          ((frmDrawPoints)exercise).Show();//cast back to frmDrawPoints and display
       }
       else
       {
           CountDots--;
           //Close frmDrawPoints
           ((frmDrawPoints)exercise).Close();//cast back to frmDrawPoints and close
           //display frmExercisesSwitchBoard
           switchBoard.Show();
       }
    }
    else
        ((frmDrawPoints)exercise).Show();//cast back to frmDrawPoints and display
}
//test if exercise is frmAbstractReasoningExercise2
else if(exercise is frmAbstractReasoningExercise2)
     {
        CountExercise2++;
        //test if CountExercise2 is more than 1
        if (CountExercise2 > 1)
        {
           //Ask user to make a choice
              if (MessageBox.Show("Do you want to re-take this exercise?", "Retaking
              Exercise Message", MessageBoxButtons.YesNo, MessageBoxIcon.Question)
              == System.Windows.Forms.DialogResult.Yes)
             {
              MessageBox.Show("WELCOME TO THIS EXERCISE!", "Welcome");
             ((frmAbstractReasoningExercise2)exercise).Show();//cast back to
             frmAbstractReasoningExercise2 and display
             }
             else
             {
               CountExercise2--;
               //Close frmDrawPoints
                ((frmAbstractReasoningExercise2)exercise).Close();//cast back to
              frmAbstractReasoningExercise2 and close
               //display frmExercisesSwitchBoard
               switchBoard.Show();
             }
             else
              ((frmAbstractReasoningExercise2)exercise).Show();//cast back to
              frmAbstractReasoningExercise2 and display
        }
        //test ifexercise is frmAbstractReasoningExercise3
        else if (exercise is frmAbstractReasoningExercise3)
             {
```

```
                CountExercise3++;
                //test if CountExercise3 is more than 1
                if (CountExercise3 > 1)
                {
                    //Ask user to make a choice
                     if (MessageBox.Show("Do you want to re-take this exercise?",
                     "Retaking Exercise Message", MessageBoxButtons.YesNo,
                     MessageBoxIcon.Question) ==
                     System.Windows.Forms.DialogResult.Yes)
                    {
                      MessageBox.Show("WELCOME TO THIS EXERCISE!", "Welcome");
                     ((frmAbstractReasoningExercise3)exercise).Show();//cast back to
                     frmAbstractReasoningExercise3 and display
                    }
                    else
                    {
                        CountExercise3--;
                        //Close frmDrawPoints
                        ((frmAbstractReasoningExercise3)exercise).Close();//cast
                     back to frmAbstractReasoningExercise3 and close
                        //display frmExercisesSwitchBoard
                        switchBoard.Show();
                    }
                }
                else
                     ((frmAbstractReasoningExercise3)exercise).Show();//cast back to
                     frmAbstractReasoningExercise3 and display
              }
              //test ifexercise is frmAbstractReasoningExercise4
              else if (exercise is frmAbstractReasoningExercise4)
              {
                CountExercise4++;
                //test if CountExercise4 is more than 1
                if (CountExercise4 > 1)
                {
                    //Ask user to make a choice
                     if (MessageBox.Show("Do you want to re-take this exercise?",
                     "Retaking Exercise Message", MessageBoxButtons.YesNo,
                     MessageBoxIcon.Question) ==
                     System.Windows.Forms.DialogResult.Yes)
                    {
                     MessageBox.Show("WELCOME TO THIS EXERCISE!", "Welcome");
                     ((frmAbstractReasoningExercise4)exercise).Show();//cast back to
                     frmAbstractReasoningExercise4 and display
                    }
                    else
                    {
                        CountExercise4--;
                        //Close frmDrawPoints
                        ((frmAbstractReasoningExercise4)exercise).Close();//cast
                     back to frmAbstractReasoningExercise4 and close
                        //display frmExercisesSwitchBoard
                        switchBoard.Show();
                    }
                }
                else
                     ((frmAbstractReasoningExercise4)exercise).Show();//cast back to
                     frmAbstractReasoningExercise4 and display
            }
            //test ifexercise is frmAbstractReasoningExercise5
            else if (exercise is frmAbstractReasoningExercise5)
            {
```

```
                CountExercise5++;
                //test if CountExercise5 is more than 1
                if (CountExercise5 > 1)
                {
                     //Ask user to make a choice
                     if (MessageBox.Show("Do you want to re-take this exercise?",
                     "Retaking Exercise Message", MessageBoxButtons.YesNo,
                     MessageBoxIcon.Question) ==
                     System.Windows.Forms.DialogResult.Yes)
                    {
                            MessageBox.Show("WELCOME TO THIS EXERCISE!", "Welcome");
                            ((frmAbstractReasoningExercise5)exercise).Show();//cast
                            back to frmAbstractReasoningExercise5 and display
                    }
                    else
                    {
                        CountExercise5--;
                        //Close frmDrawPoints
                         ((frmAbstractReasoningExercise5)exercise).Close();//cast
                     back to frmAbstractReasoningExercise5 and close
                        //display frmExercisesSwitchBoard
                        switchBoard.Show();
                    }
                }
                else

                     ((frmAbstractReasoningExercise5)exercise).Show();//cast back to
                     frmAbstractReasoningExercise5 and display
            }
```

Figure 4.5: Overview of C# program segment of the SwitchBoard code module

Each subsequent workout consists of different games, exercises, and questions, or combinations thereof in a manner that stimulates different brain functions related to abstract thinking and the different cognitive levels as described earlier in this chapter. Each workout module is coded in such a fashion as to allow the automatic amendment and customization of exercises by the module based on the particular user's collected performance data to optimize the relevant exercise. This was accomplished by making use of learning decision tree algorithms, albeit limited in terms of leaf nodes (decisions), subsequent entropy and therefore limited in scope.

All functional and conceptual aspects of the intervention were demonstrated to the psychologist over a period of two days. The purpose of this engagement was to ascertain the following:

- if the design and layout of the intervention encouraged:
    - the use thereof on a subliminal level and invoked a sense of trust amongst its users;

  - emotions of excitement and anticipation; and
  - would not be perceived as tedious and boring to use over the envisaged period of use (7 months).
- that the final versions of the games, exercises, and questions related to the different levels of cognitive stimulation where true representations of the different psychometric principles investigated;
- the different workout repositories stored the correct interrelated games, exercises, and questions for each level; as well as that
- the intervention would stimulate the identified and subsequently targeted cognitive processes and associated areas of the brain based on the composition and constituents of the games, exercises, and questions.

Following the review of the intervention and the interrelated functional aspects, the graphical user interface and the content repository, these suggestions were made by the psychologist:

- Decrease the number of workout modules that is controlled by the SwitchBoard module from 10 to 5. The psychologist felt it would be more beneficial rather to increase the number of options the different modules relevant to each targeted cognitive process could select from the repository than to extend and increase the number of workout modules or to repeat workout modules that targeted the same cognitive processes. By decreasing the number of modules and increasing the pool of games, exercises, and questions in the repository may not affect the processing performance of the intervention noticeably, but it would allow for each participant engaging the intervention to traverse different levels of the intervention within the envisaged timeframe set aside for interaction per week. This progress through the different "stages" of the intervention would mean, in turn, that the participants would be exposed to a greater variety of content of varying difficulty and targeted stimulation. The last five modules were removed from the SwitchBoard code module and the content repository subsequently increased.

- Include functionality which would allow the user to save his/her progress throughout the interaction process. This functionality will allow users to save their progress and continue their following interaction session with the intervention from the point of interaction saved.

- Include automatic save functionality. This will save the point of interaction relevant to each user's interaction at the time the system locks a user out due to elapsed interaction time. This will also allow the user to continue from the saved point of interaction when he/she interact with the system again.

- Increase the pool of warm-up games, exercises, and questions to allow for more variety and decrease the probability of users relying on recall to complete the relevant exercises.

All of the suggested alterations were made and applied to the intervention. The application of the suggested alterations led to each user being assigned a specific computer to use during interaction sessions, as the intervention does not prescribe to a client-server architecture and relies on the local storage and processing power of the computing device. If a user saved his/her progress whilst using a particular computer, the relevant saved point of interaction would only be available on that computer, irrespective of the number of different users.

Figure 4.6 depicts how the graphical user interface (GUI) for the administrator has changed after the suggested changes were applied.

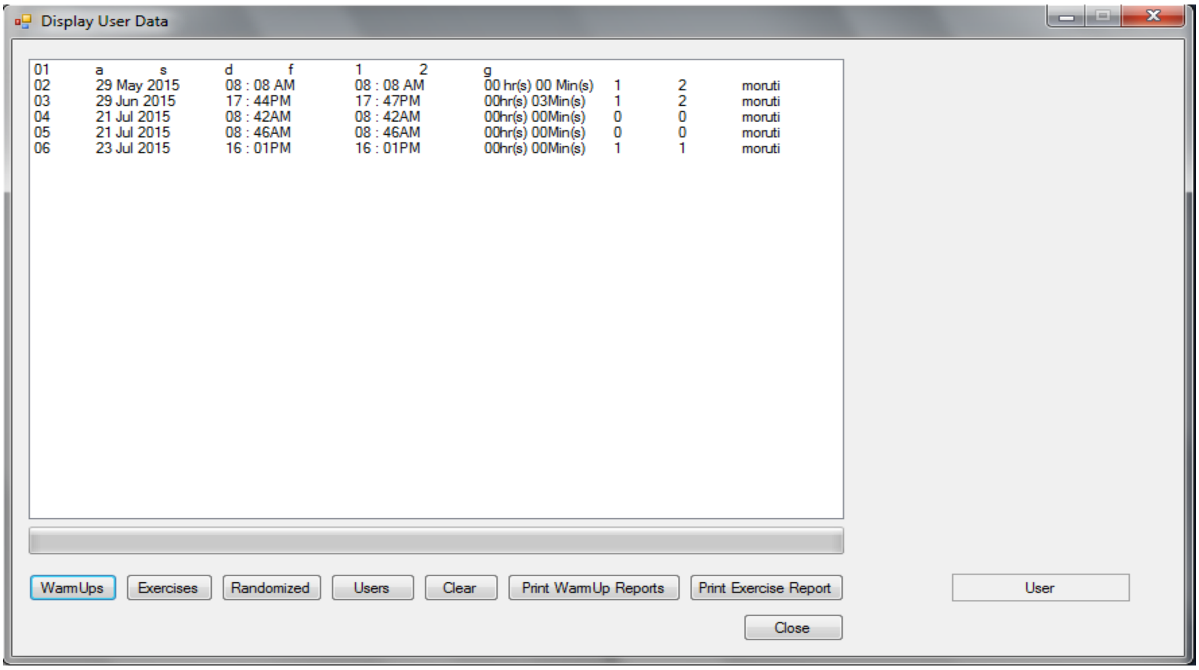

Figure 4.6: A snippet of the administrator view interface of the warm-up section

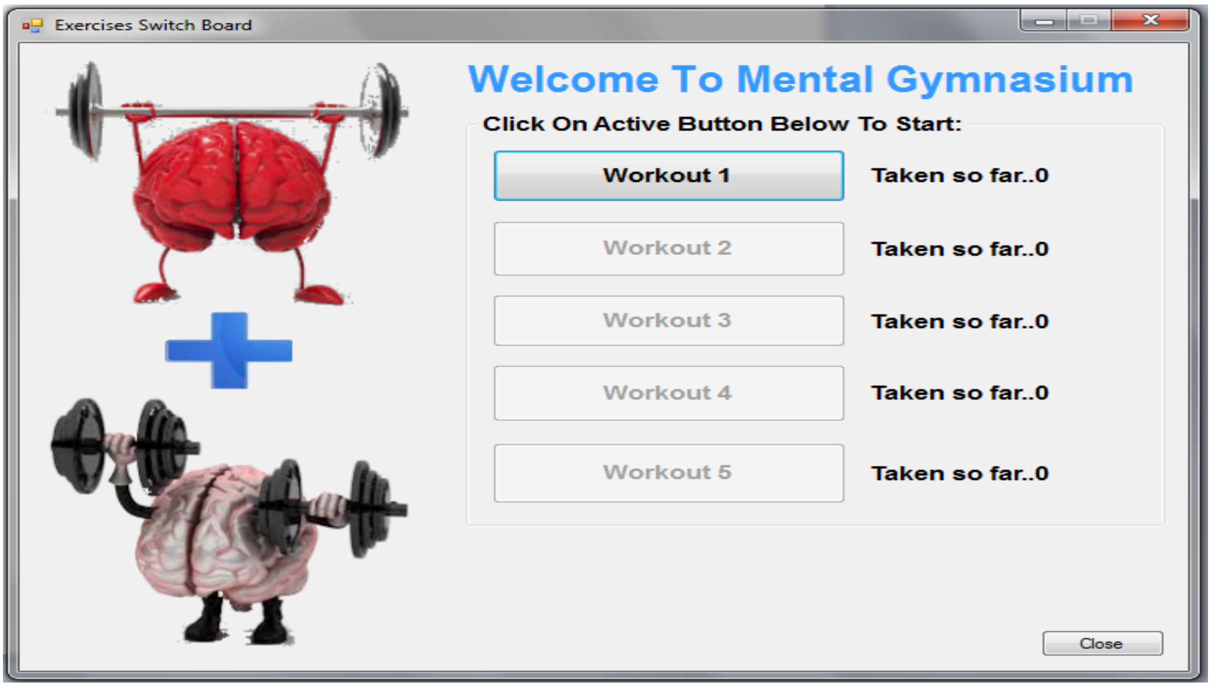

Figure 4.7: Overview of the GUI that initiates the SwitchBoard module for different workouts

Figure 4.7 depicts the GUI that initiates the SwitchBoard code module. The different buttons make use of the methods in the SwitchBoard code module to access and initiate the different workout code modules, which in turn make use of the recorded performance and progress data of the relevant participant to construct the combination of games, exercises, and questions for each level. If no previous data exists, the code modules revert to the lowest level of combinations of questions, exercises and questions for all the different workouts.

In addition to the buttons, details of how many times the user accessed each code module are outlined next to the relevant button. Each one of the workout code modules can be interacted upon more than once if it has been completed successfully during the current session.

4.10.2 Warm-up Exercises

According to Betker et al. (2007), the brain's mode of idea generation or information processing needs to be "switched on". This can be accomplished through engaging brain warm-up exercises, like, for example, composing a list of one word for each letter of the alphabet, with the challenge of composing words that are rarely used like *asphyxia* or *zoochemistry*. Furthermore, Chi and Snyder (2012) propose that doing cognitive "warm-up" before any strenuous cognitive stimulation or exertion can be beneficial when considering the cognitive processes and the establishment of new neural connections and pathways.

Warm-up exercises before any activity that requires focus and attention can also lessen the strain on the cerebral cortex. Less cerebral strain can assist the brain to engage synapses that usually do not work together to do so, which in turn, has a positive influence on the ability of the brain to form the new pathways between neurons once a particular activity that requires our focus and attention is engaged, for example. Ultimately, this process and new pathways help us, as humans, to sharpen a new skill we are attempting to master, learning something new or stamping out bad habits that formed over time (Everitt & Robbins, 2005; Mackey, Whitaker & Bunge, 2012).

Existing exercises that act as mechanisms through which the brain can be "warmed up" by reviewing related scholarly articles were investigated, and relevant games and exercises were derived and developed from these mechanisms. This pool of games and exercises were incorporated into the intervention with the aim to optimize cognitive performance and the underlying process of neuroplasticity. The aforementioned process of warming up the brain was incorporated into the study as part of the study's interaction protocol. The interaction protocol is available for perusal in appendix D.

A dedicated code module records participant interaction with regard to the developed warm-up games and exercises as well as performance data like, for example, the time it takes a particular participant to complete a particular workout game or exercise presented. The same module also concurrently randomizes the references to the warm-up games and exercises and selects a set of games and/or exercises from a dedicated warm-up content repository. The module then automatically launches selected warm-up workouts each time a participant initiates an interaction session with the intervention. The warm-up session precedes any other engagement with the workout content developed. Each participant in the experimental group(s) is required to complete a set of warm-up games or exercises or combination of both irrespective of the level of interaction achieved before the particular instance of participant interaction with the intervention.

The intervention allows a participant subsequent access to the games, exercises, and questions that target the cognitive processes related to abstract reasoning once the relevant participant has successfully completed the presented warm-up session.

Arguably, the warm-up section of the intervention could lead to frustration on the part of the participant and may affect the succeeding interaction with the cognitive workout sections of the intervention negatively. With that in mind and with the assistance of the psychology expert, all warm-up activities were developed with fun and low cognitive strain in mind, whilst attempting to keep the user engaged. To illustrate: one of the measures that was put in place in an attempt to keep the user engaged during the warm-up sessions, was to challenge the user to beat his/her own recorded best time when interacting with a particular warm-up game or exercise that the user had already completed during a previous interaction session.

With brevity in mind, the rest of this section is dedicated to elaborate on one particular example of one of these so-called warm-up workouts. During the literature review, the researcher discovered a pen-and-paper based game that was used in a study conducted by Chi & Snyder (2002). The aim of the game is to connect 9 separate dots by making use of only four consecutive lines without lifting the pen and without tracing any line more than once. This game engages the cognitive process of *lateral thinking* – a cognitive process linked to abstract reasoning (Kihn, 1995).

Figure 4.8 depicts a limited overview of the C# code module specifically developed to enable the intervention to draw the nine dots on the GUI to allow the user to connect the presented dots. The module also reviews actions on the part of the user and scrutinizes the process to ensure that the user adheres to all the rules of the game whilst drawing the lines between the dots based on the user's interaction.

The particular code module was developed to also include the following functionality relevant to the game being discussed:

- Create and display a timer on the interface whilst performing a subsequent iterative negative countdown from 6 minutes to 0 seconds once the interaction with the game has commenced.

- Calculate the number of lines the user has used to connect the dots during his/her attempt whilst calculating and displaying the number of lines the user has left to use to complete the game.
- Assess if the user has succeeded in connecting all of the dots, irrespective and independent of a particular pattern.
- Lock the interface if:
  - The allotted time to complete the game has elapsed.
  - The user did not adhere to the rules of the game.
  - The user has completed the game successfully.
- Record data such as:
  - The user number of the participant logged in.
  - The date and time related to when the interaction commenced.
  - The number of times a specific participant has interacted with the specific game.
  - The number of times a specific participant has successfully completed the game as well as the number of times the participant was unsuccessful in completing the game relevant to each interaction session.
  - If a participant was unsuccessful in his/her attempt to complete the game, why did he/she fail? Did the allocated time elapse before the participant could complete the game? Did the user fail to adhere to the rules of the game? Did the user run out of lines to use?
  - The time that has elapsed for each successful completion of the game as well as the amount of time left on the countdown timer for each successful completion of the game.
  - The number of minutes, hours, days, weeks or months that have elapsed between the current interaction session of the participant with the game and the most recent preceding interaction with the game.

- Display relevant messages with regard to the success or failure of the particular attempt to the participant.

All of the participants were made aware of all of the interaction data that would be recorded by the intervention during every interaction session as well as their rights with regard access to and viewing the collected data per reasonable request, as mentioned earlier in this discourse. The participants consensually agreed to all the terms and conditions stipulated in the memorandum of understanding (MOU) between the participants and the researcher. A copy of the MOU is available for perusal in appendix A

```
class DotDrawing
{
      public DotDrawing()
      {
        Dots = new List<Dot>();
        DotRadius = 10;
        ColumnCount = 5;
        RowCount = 5;
        this.RowSpacing = 40;
        this.ColumnSpacing = 40;
      }
      public void Render(Graphics g)
      {

        SolidBrush_brush1=new
SolidBrush(ColorTranslator.FromHtml("#E3E8E7"
));
        SolidBrush_brush2=new
SolidBrush(ColorTranslator.FromHtml("#009aff"
));
        this.Dots.Clear();
        float x = 0;
        float y = 0;
        for (int i = 0; i < RowCount; i++)
        {
          for (int j = 0; j < ColumnCount;
j++)
          {
        Dot dot = new Dot();
        dot.Location = new PointF(x, y);
        if(i == 0 || j == 0 || i == 4 || j ==
        4)
        g.FillEllipse(brush1, dot.Location.X,
        dot.Location.Y, DotRadius, DotRadius);
        else
        {
         g.FillEllipse(brush2, dot.Location.X,
        dot.Location.Y, DotRadius, DotRadius);

         x += (DotRadius + ColumnSpacing);
         Dots.Add(dot);
                 }
           }
```

```
protected void
frmDrawPoints_MouseUp(object sender,
MouseEventArgs e)
{
  Dot dot =
this.drawing.GetDotFromPoint(e.Locatio
n);
    if (dot != null)
    {
      Line line = new Line();
      line.X1 = firstDot.Center.X;
      line.Y1 = firstDot.Center.Y;
      line.X2 = dot.Center.X;
      line.Y2 = dot.Center.Y;
      Lines.Add(line);
      //Display clear buttons
      btnClearAllLines.Enabled = true;
      btnClearOneLine.Enabled = true;
      update -= 1;//update number
      if (update >= 0)
         UpdateLineCount();//
      //Call paint event to redraw
      Invalidate();
     }
private void
btnClearLines_Click(object sender,
EventArgs e)
{
 if (Lines.Count > 0)
 {
   update = 4;//reset the number
   UpdateLineCount();//Display lines
to connect dots
   Lines.Clear();
   countClearAllLines++;
   DisableClearButtons();
   Invalidate();//Call paint method to
redraw
 }
 else
   DisableClearButtons();
 }
private void
```

<pre>   x = 0;
          y += (DotRadius +this.RowSpacing);
      }
(Acharya, et al., 2013)   }
 public Dot GetDotFromPoint(PointF point)
 {
    for (int i = 0; i < this.Dots.Count; i++)
    {
         RectangleF rect =
         this.Dots[i].Bounds;
         rect.Inflate(new SizeF(5, 5));
         Region region = new Region(rect);
         if (region.IsVisible(point))
         {
       return this.Dots[i];
         }
     }
               return null;
   }
}</pre>
	<pre>btnClearOneLine_Click(object sender,
	EventArgs e)
	{
	 if (Lines.Count > 0)
	 {
	   update += 1;//update number
	   UpdateLineCount();//Display lines
	connect dots
	   Lines.RemoveAt(count);
	   if (Lines.Count == 0)
	   {
	     DisableClearButtons();
	     countClearOneLine++;
	     update = 4;//reset the number
	   }
	else
	{
	  btnClearOneLine.Enabled = false;
	  btnClearAllLines.Enabled = false;
	}
	}</pre>

Figure 4.8: A C# program snippet of the code module that controls the nine-dot four-line connection game

Figure 4.9 is a graphic representation of the 9 dots 4 lines mental warm-up challenge. The user is presented with the 9 dots and requested to connect all 9 dots with 4 lines by using the computer mouse. The code module mentioned in the preceding section draws and displays the lines, as the user moves the mouse pointer from one dot to the next, whilst holding down the left mouse button. As soon as the user engages the left mouse button for the first time, the countdown timer is activated. Once the user releases the left mouse button, the intervention records that one line was used thus far to complete the exercise and subtracts the line from the allotted 4 lines. The 3 lines that are left to successfully complete the game are updated and displayed to the user.

Two buttons on the GUI are also activated once the left mouse button is engaged for the first time. One of the buttons allow the user to either clear all of the lines that have been drawn by him/her thus far, and the other to clear the most recent line drawn. If the user erases the most recent line by clicking the “Clear One Line” button, and clicks the button again, the line drawn before the deleted line is erased. The user can use this button to clear one line after the other until all lines have been erased. The countdown timer does not stop the process of counting down and displaying the time the user has left to complete the challenge if the lines are erased by either of the two buttons.

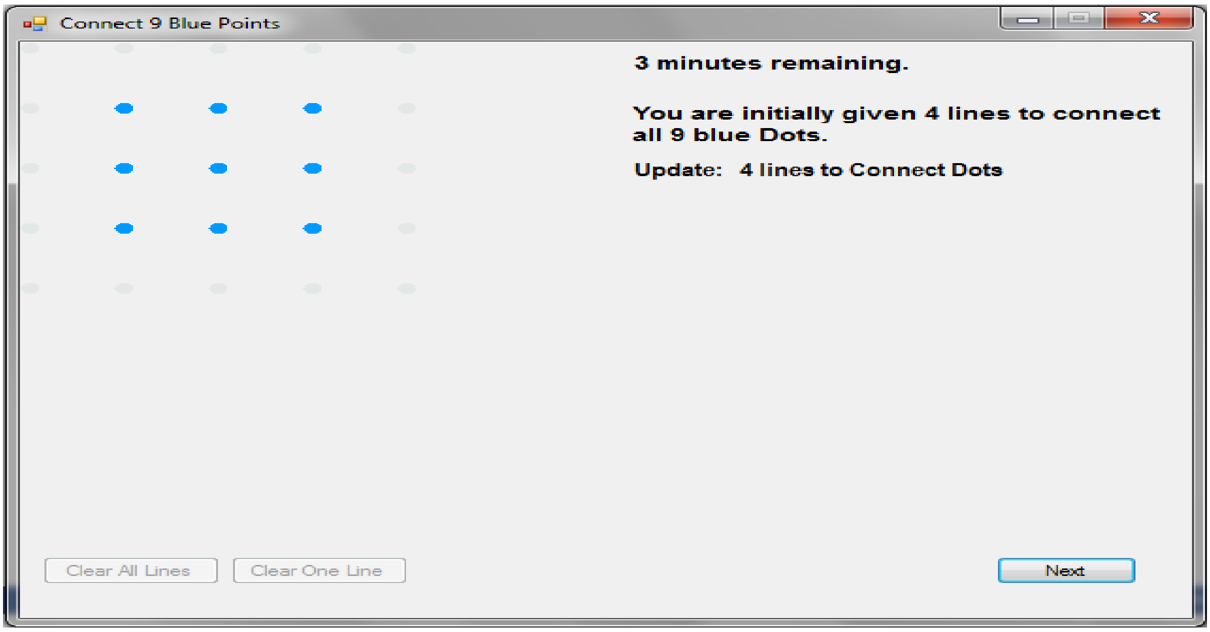

Figure 4.9: Connection of nine dots using only four lines module

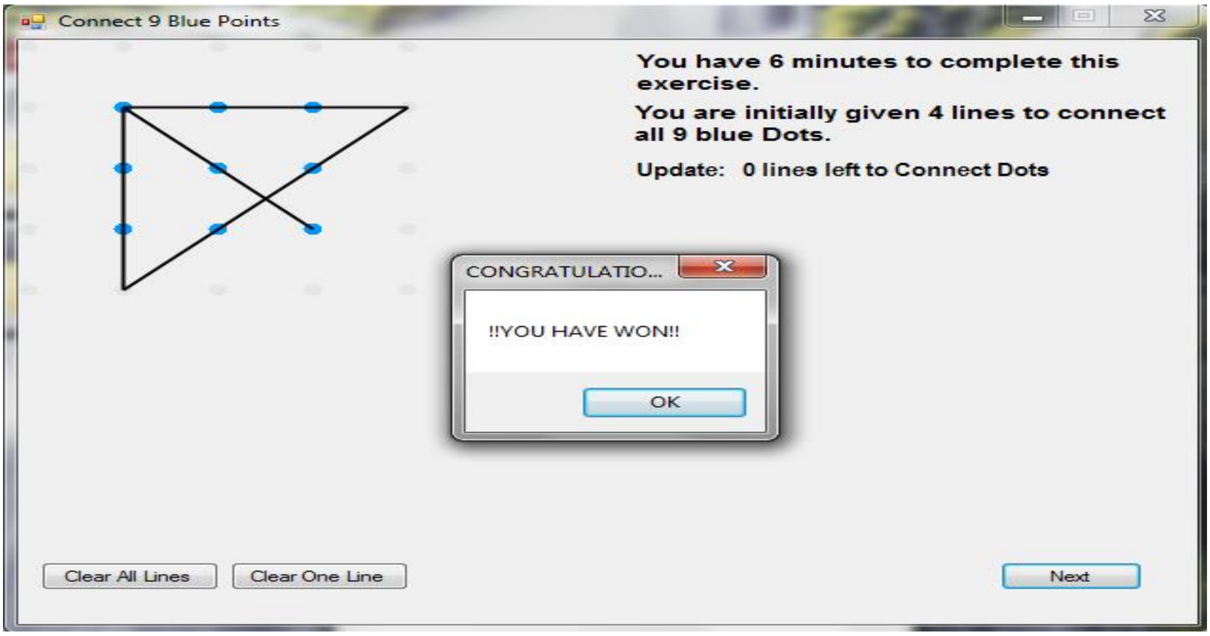

Figure 4.10: Connection of nine dots using only four lines module

The game continues until the allotted time to complete the game has elapsed, the user unsuccessfully used all of the allotted lines in an attempt to complete the exercise, did not adhere to the rules of the game, e.g. traced over an existing line or has complete the exercise successfully. Figure 4.10 depicts the successful completion of the game with the accompanying message.

Figures 4.11 and 4.12 illustrate two unsuccessful attempts to complete the game. In Figure 4.11 the user failed to connect all of the dots with the allotted 4 lines and Figure 4.12 demonstrates a failed attempt with regard to elapsed time.

Each time a user fails to complete a warm-up game or exercise, the system records which game or exercise was failed and why the user failed to complete the exercise. A separate code module then omits the game or exercise that the user failed to complete, randomizes the remaining references to the warm-up games and exercises and selects a new set of warm-up games, exercises or combination of both. Thereafter, the user is presented with a set of newly selected warm-up workouts and is prompted to engage with it. This process continues until the user has successfully completed the entire warm-up session.

The user is allowed to continue to the first section of the psychometrically based primary cognitive workouts, i.e. level 1 of the workouts once he or she has successfully completed a particular set of warm-up games or exercises. The intervention also records the success and all other relevant data as explained earlier in this section.

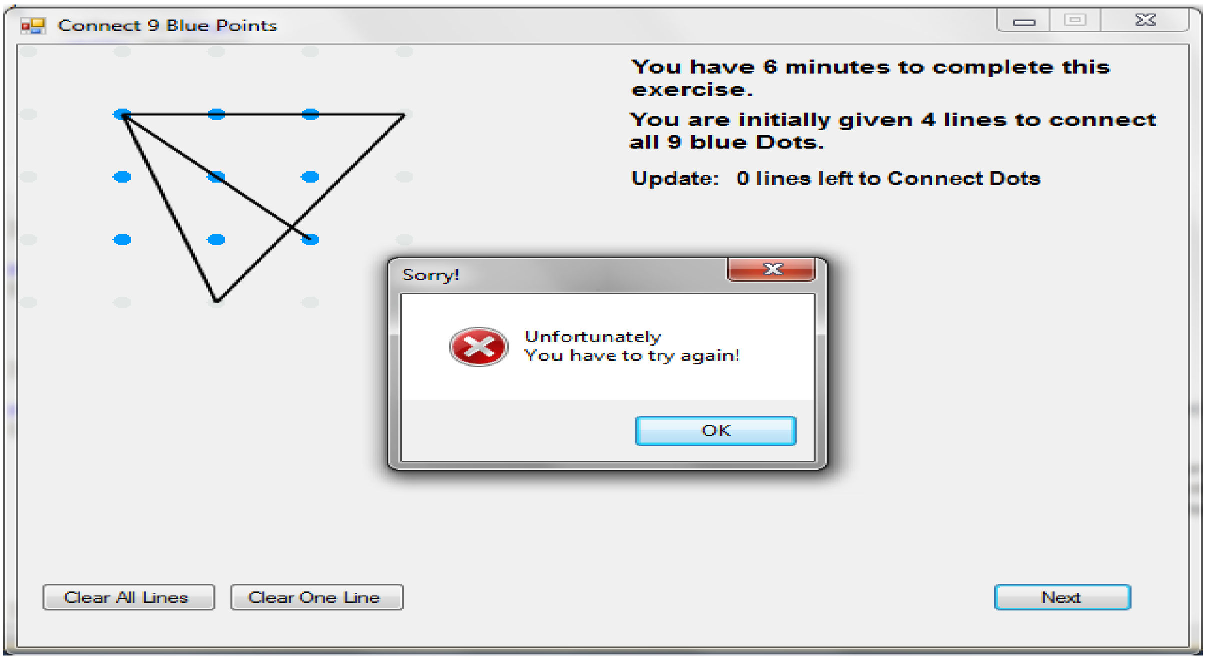

Figure 4.11: Connection of nine dots using only four lines module

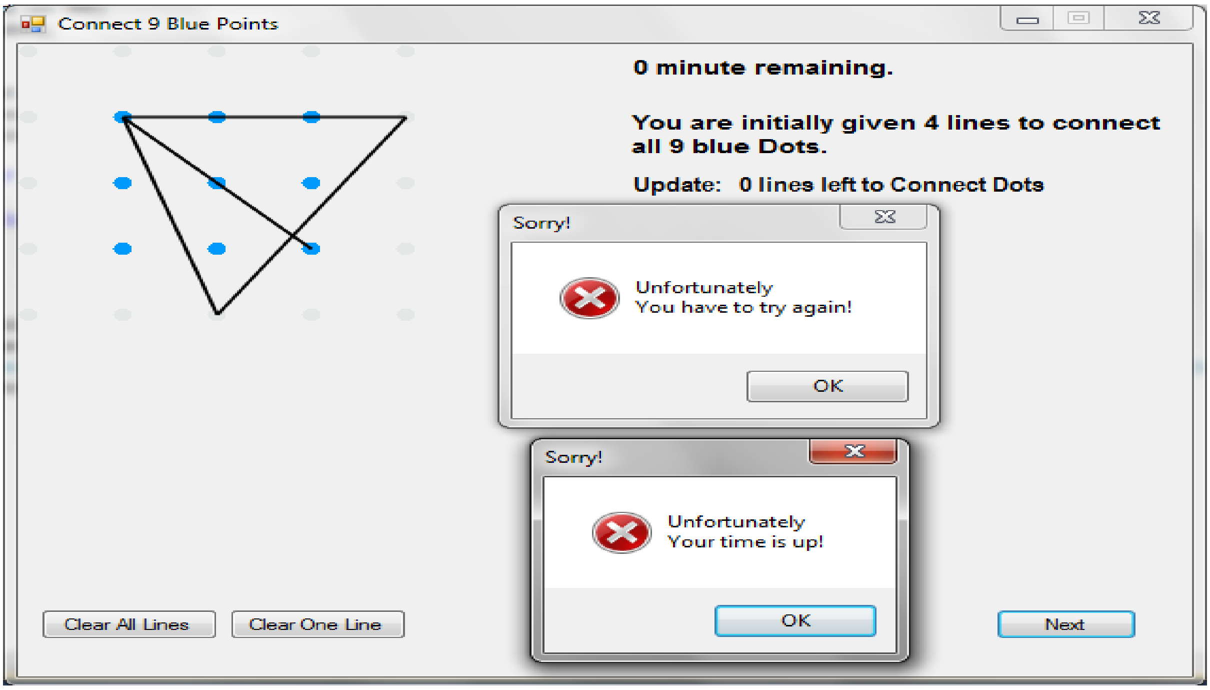

Figure 4.12: Connection of nine dots using only four lines module

Once engaged by the user, usage and performance data for each of the warm-up games or exercises that reside in the content repository is recorded. Different games have different rules and different parameters, i.e. the time parameter may vary from one game to the next. In short, the code modules were developed by employing the OOP principles of super classes, sub-classes, inheritance and polymorphism in a multi-threaded environment to address the particular challenge whilst taking into account the performance related parameters of the intervention.

4.10.3 Addressing Abstract Reasoning: The Primary Cognitive Workouts

Details pertaining to the components of the intervention, the relevant code modules developed and the functionality of the different code modules were covered in detail in section 4.10.1. This section gives an overview of one of the developed exercises that is rooted in psychometric principles and concepts.

The five levels of interaction that a user has to traverse throughout his/her engagement with the intervention is comprised of a subset of psychometrically-driven games, exercises, and questions which was developed to target and stimulate the working memory and other cognitive processes that can be linked to abstract reasoning abilities in individuals as discussed thus far.

As mentioned in section 4.10.1, each subset of workouts grows in complexity and are constructed from a repository that respond to a code module created with the purpose of generating random content of the content repository. Level 1 workouts are, for example, less complex in nature than level 2 workouts, and so forth. This does not mean that, as the participant advances, all of the level 1 workouts are necessarily simple. Although they too advance in complexity, they are less complex overall than level 2 workouts. A dedicated code module scrutinizes the historic participant performance and retrieves the level of interaction the participant has achieved thus far before the random content generated.

Each game, exercise and question in the content repository was assigned a representative number that indicates the related level of complexity associated with the particular game, exercise or question. The numbers 1 through to 5 were assigned to the content with the aid of the psychologist who was consulted during this study. These numbers indicate the different levels of complexity. The number 1 was assigned to the least complicated content, the number 2 to the complicated content, the number 3 to content that was deemed to be of intermediate complexity, the number 4 was assigned to content that was complex and finally, the number 5 was assigned to content that was categorized as very challenging/complex in nature. The researcher referred to these numbers as the content's *complexity rating*.

Initially, a level 1 workout would, for example, consist only of content that was assigned a complexity rating of 1 throughout. This means that, if a level 1 workout consisted out of 6 games, exercises, questions or a combination thereof, only content with a complexity rating of 1 will be randomly selected from the content repository. As the user advances, different combinations of content with different complexity levels are generated based on the user's performance.

Consider figure 4.13 as an example of how the content is constructed based upon user performance data.

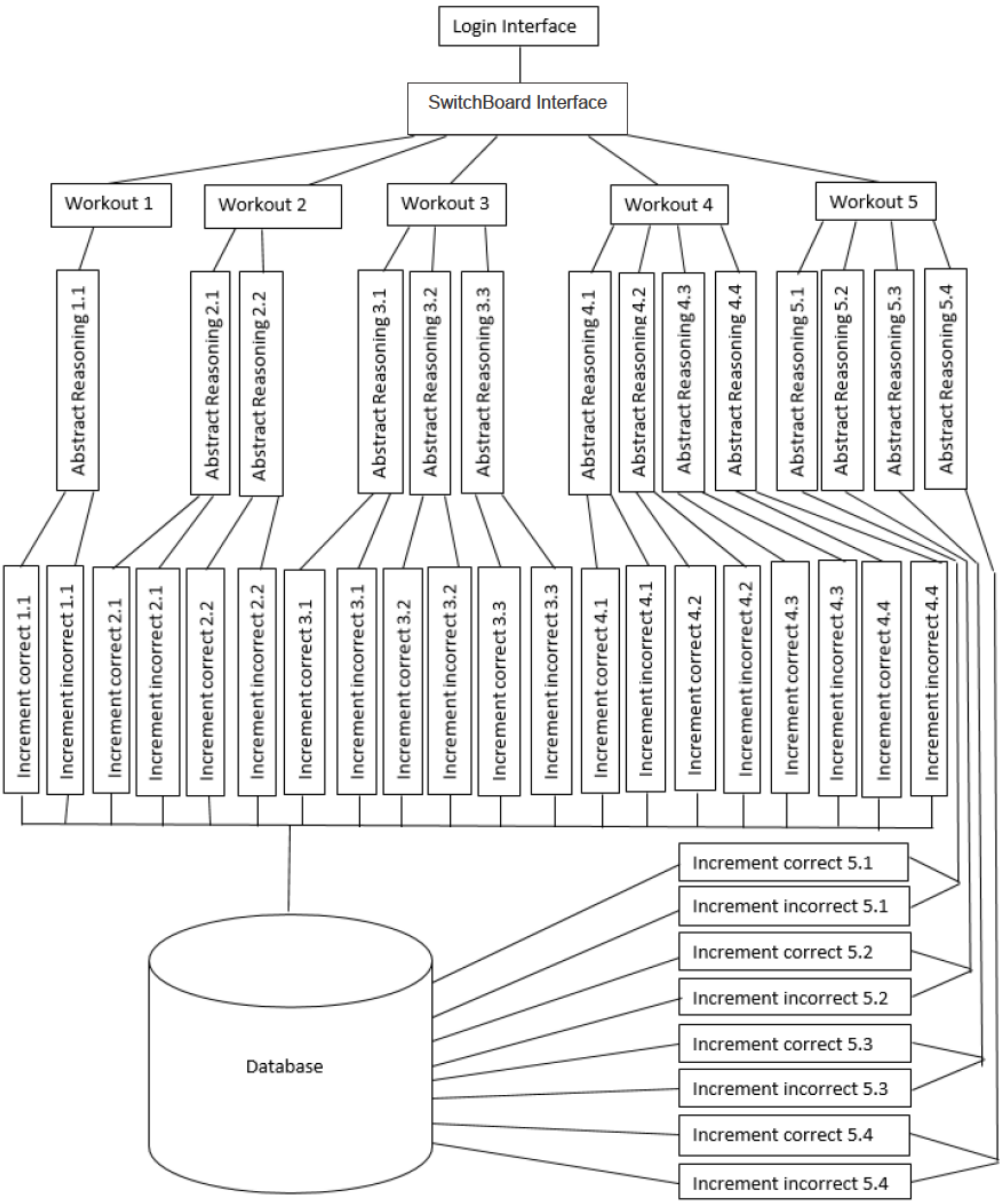

Figure 4.13: Collection of content based on user performance data

The C# code snippet in figure 4.13 is an excerpt from a code module that was developed to generate random content and assign the content to button controls. This particular workout comprises of 5 different exercises. The approach of creating random content from a content repository was not only utilized to keep the working memory process engaged throughout the interaction, but also to negate the possibility that a user could rely on his/her long-term memory to complete, for example, exercises that would otherwise be repeated with the same content constituents.

```
//Randomize method for workout 1,2,3,4,5

private void Randomize()
{
       isTrue = true;
       while (isTrue)
       {
           index = random.Next(0, 5);
           if (index != track)
           {
               track = index;
               isTrue = false;
           }
       }
}
public frmAbstractReasoningExercise3()
{
            InitializeComponent();
            DataAccess.Connect();
            //connect to content repository
            .
            ...
            ...
            ...
            .
            second = 0;
            minutes = 3;

            //set starting time and date
            TimeDate.StartTime(true);
            TimeDate.StartDate(true);
            //Hide minimize, maximize and close buttons
            this.ControlBox = false;

            buttons.Add(btnEx3Grp1A);
            buttons.Add(btnEx3Grp1B);
            buttons.Add(btnEx3Grp1C);
            buttons.Add(btnEx3Grp1D);
            Randomize();
            //Swap button content randomly
            DataAccess.SwapButtons(buttons, index, ex3Q5CorrectB);
            //Removes group 1 buttons
            buttons.Clear();

            //Add exercise 3 question 6 buttons
            buttons.Add(btnEx3Grp2A);
            buttons.Add(btnEx3Grp2B);
            buttons.Add(btnEx3Grp2C);
            buttons.Add(btnEx3Grp2D);
            Randomize();
            //Swaps buttons randomly
            DataAccess.SwapButtons(buttons, index, ex3Q6CorrectB);
            //Removes group 1 buttons
            buttons.Clear();
```

```
            //Add exercise 3 question 7 buttons
            buttons.Add(btnEx3Grp3A);
            buttons.Add(btnEx3Grp3B);
            buttons.Add(btnEx3Grp3C);
            buttons.Add(btnEx3Grp3D);
            Randomize();
            //Swaps buttons randomly
            DataAccess.SwapButtons(buttons, index, ex3Q7CorrectC);
            //Removes group 1 buttons
            buttons.Clear();
            tmrSecond.Start();
}
```

Figure 4.14: An excerpt from a code module's randomized method

Figure 4.15 is a representation of the randomly generated exercises generated by the code partially represented in Figure 4.14. As with all the games, exercises, and questions, the depicted exercise is based on scientifically proven psychometric and psychological principles and concepts.

Consider figure 4.15 and the exercises depicted. These exercises were developed to specifically target the cognitive capacity of the user to solve each of the posed problems by:

- considering the images in terms of concepts;
- generalizing the concepts;
- detecting patterns and relationships between object/ concepts; and finally
- drawing logical conclusions from what was observed.

All of the above-mentioned abilities are directly linked to the ability to think in an abstract manner, therefore, if a participant is able to complete the depicted exercises successfully, it may be indicative of the participant's ability to think in an abstract manner. A workout content, is considered successfully completed if at least a pre-determined value as per the recommendation of the psychologist involved, was completed with success.

The researcher may also be inclined to deduce that, if a participant is unable to complete the exercises successfully, he/she reasons in a more concrete fashion and struggles to generalize concepts, ideas, objects and so forth. Concrete thinkers tend to problem solve in a systematic fashion based on what they perceive whilst keeping to the literal representation of things or considering ideas and objects as specific items (Farlex Partner Medical Dictionary, 2016).

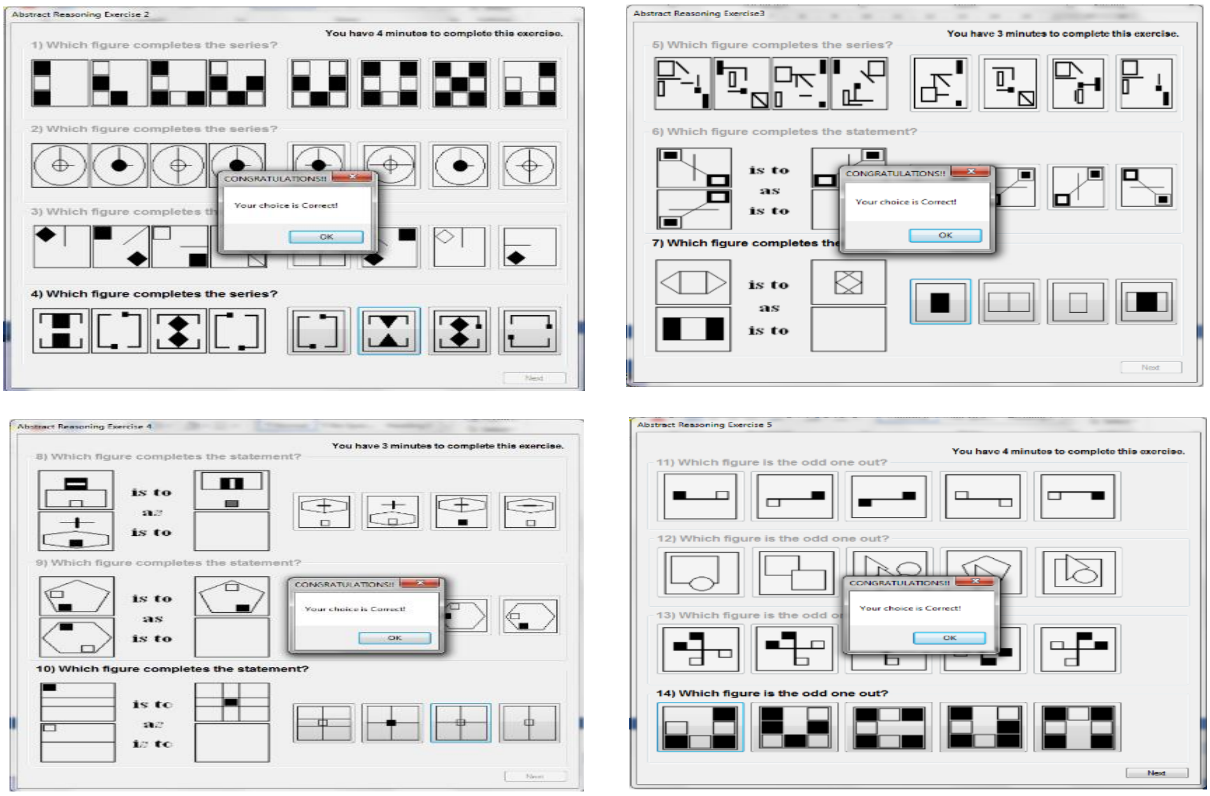

Figure 4.15: A graphical representation of a psychometric-driven exercise

The recorded participant performance data relevant to the workouts such as the exercises depicted in figure 4.15 could prove useful to track and quantify participant abstract thinking development or the absence thereof.

4.11 System Database Design and Implementation

Information has been described as the lifeblood of any organization. Organizations constantly aim to collect, analyse and interpret high quality data in their respective fields of operation to help ensure the success of a particular enterprise and gain a competitive edge. Quality information, in turn, results in good and effective managerial decision-making (Bades, 2014; Hassan & Wang, 2015; Mukred & Yusof, 2015).

In addition to the importance of quality, current data and information, more and more organizations are reflecting on and mining historic data to gain the competitive edge, identify market trends and revise business operations. Mukred and Yusof (2015) consider the preservation, protection and storage of all data and information, in whatever format, as crucial to both the owner of the data and the subsequent users thereof. In the medical arena, for instance, Henderson (2015) asserts that an exploration of the historical medical records of patients proved very beneficial as an informational blueprint of patient health and could greatly support crucial decision making toward overall patient wellbeing.

The data collected by the intervention during each of the interaction sessions is considered as the lifeblood of this study as well. Data collected, like the participant performance data, is used by the intervention to customize and optimize the workouts to a certain degree with regard to each participant. The analysis and interpretation of the data will be crucial in the researcher's attempt to assert if and how an IT intervention can be developed to influence abstract thinking abilities in human beings, positively, negatively or at all. The proper storage of all the digital data collected by the intervention is therefore of absolute importance.

There are many software solutions in the form of relational database management systems (RDBMS). The researcher identified and investigated three possible solutions, considered the positive and negative attributes of all and made a subsequent decision about which solution would best suit the needs of the researcher, whilst taking into account feasibility aspects.

For this study, the researcher considered Oracle, MySQL, a cloud storage service and Microsoft (MS) Access. The researcher's shortlist was based on the RDMSs readily available in the computer laboratories and the institution of higher learning where this study was conducted.

The researcher provides a brief overview of each of the mentioned RDMSs the study considered in the following section.

- Oracle

Powell and McCullough-Dieter (2007) refer to Oracle as a fully scalable relational database architecture, often used by global enterprises to manage and process data across worldwide and local area networks. Oracle was also the first commercially availability RDMS on the market. Oracle offers a powerful but complex database solution. The complexity of the Oracle database solution and the limited experience of the researcher with Oracle were its main detracting factors.

- MySQL

MySQL is a full-featured RDBMS originally developed as freeware and the source code is freely available (Vladimirovich & Vladimirovich, 2013). MySQL has recently become a part of Oracle. The main detracting factors of MySQL include reported stability issues and poor performance scaling. Although the volume of data collected by the intervention may not be remotely close to the volume of data MySQL can handle, the possibility that problems could arise as well as the fact that the developer-driven development of MySQL has been dwindling since Oracle acquired SUN Enterprises, influenced the researcher decision against it.

- Cloud storage services

Zhang et al. (2015) describes cloud storage as a service model in which data is stored, maintained, backed up remotely, and accessed by users over a network, typically the Internet. The main detracting factors for not considering cloud storage services beyond this point included unreliable and inconsistent internet connectivity in the named computer labs at the time the study was conducted as well as the financial impact such services could incur.

- MS Access

MS Access is a relational database product developed by Microsoft. It uses the Jet Database Engine for data storage and, according to Adamski et al. (2013), it can stably handle small to medium database deployments (Adamski, Finnegan & Scollard, 2013). Although Access has many limitations, it was readily available, provided easy development and deployment and incorporated enough security to suit the needs of the researcher. If more security becomes necessary in the future, one can always consider using structured query language (SQL) Server as the database engine with an Access front-end.

An overview of some of the tables that was developed in MS Access is presented in figure 4.16.

tblUser

Field Name	Data Type
uusername	Long Text
upassword	Long Text

tblMin

Field Name	Data Type
ausername	Long Text
apassword	Long Text

tblDotConnection

Field Name	Data Type
dotID	AutoNumber
dotStartDate	Long Text
dotStartTime	Long Text
dotStopTime	Long Text
dotDurationTime	Long Text
dotCorrect	Long Text
dotErrors	Short Text
dotUsername	Long Text
dotPassWord	Long Text

tblExercise

Field Name	Data Type
ID	AutoNumber
exStartDate	Short Text
extartTime	Short Text
exStopTime	Short Text
exDurationTime	Short Text
exQuestions	Short Text
exCorrect	Short Text
exIncorrectTimes	Short Text
exUsername	Short Text
exPassWord	Short Text

Figure 4.16: An excerpt of the MS access database design

4.12 Questionnaire

To add value to the study, the researcher obtained additional information, i.e. opinions from the experimental group members, to gauge the overall experiences of the members during the interaction with the application. According to Rauschenberger et al. (2013), a rigorous and sound questionnaire can pose a significant challenge. The questionnaire that was developed was based on the principles and layout of three existing questionnaires, namely the User Experiences Questionnaire (UEQ), Game Experience Questionnaire (GexpQ) and Game Engagement Questionnaire (GengQ). The UEQ is an assessment tool, in the form of a questionnaire, specifically developed to comprehensively gauge user impressions after interaction with an interactive product; the GexpQ assesses the subjective experiences of different video game players; and the GengQ assesses the experience of video game players who are susceptible to video games' violence (Norman, 2013).

Questionnaires make frequent use of rating scales to assess behaviour and experiences among participants. Rensis Likert is the originator of the generally used Likert-scale, developed to scale responses in survey research (Salkind, 2009). The questionnaire developed for this study also employed a Likert-scale, as well as open and closed-ended questions to gather relevant data. The final version of the questionnaire is available for scrutiny in Appendix B.

The following information relevant to the rights of the participants was shared with the members of the experimental group:

- Each participant could withdraw from completing this questionnaire at any time.
- All necessary measures were taken to ensure the confidentiality of this survey.
- No names, surnames or other identifying credentials had to be provided, thus each participant had the right to stay anonymous.
- A copy of the completed report based on the analysis of the questionnaires would be made available upon participant's reasonable request.

The questionnaire was administered under controlled conditions in a controlled laboratory setting. All participants were physically separated whilst completing the questionnaire. This was done to promote answers with a high degree of validity, whilst aiming for the lowest possible subjection to other participants' influence.

4.13 Chapter Conclusion

This chapter provided the reader with an overview of the different components of this study, a summary of how the research process was engaged, which empirical data collection tools were used, and insights into the development of the intervention. This was aimed at giving the reader a clear understanding of this study.

Psychological/psychometric methods and instruments available to gauge the abstract thinking abilities of individuals were also explained and work in fields such as neurology and application development, to name but a few, were highlighted.

Important insights on how the researcher has initiated the study, the background of the participants and how they were selected, and the reasoning behind the establishment of different user groups and their roles were provided. Furthermore, the pre and post-tests, their development and content, were also explained.

After highlighting the fundamental differences between structured programming and OOP, the chapter continued to provide an extensive overview of the intervention, its constituents, the development thereof as well as the different code modules and their functionality. Excerpts of code as well as examples of the GUI of the intervention were provided. The reasoning behind how and with what purpose the cognitive workouts were designed was mulled over upon and explained.

Finally, the researcher provided an outline of the RDBMS that was employed as well as the arguments that led to the choice of the particular RDBMS employed. The chapter concluded with an overview of the questionnaire that was developed to collect the data relevant to the participants' perception of the intervention and their interaction with it.

Chapter 5 focuses on the analysis, presentation and deliberation of the data collected.

CHAPTER 5

FINDINGS

5.1 Pre-Assessment Discussion of the Data Collected

This chapter is dedicated to the interpretation and discussion of the analysed data pertaining to the two sections of the assessment that formed the constituents of the pre-test, as discussed in the previous chapter.

Also included in this chapter is a comparative representation of student performance in a subset of modules (subjects) that form part of the first-year curriculum at the UoT related to this study. Some of these modules require recall and recognition on the part of the student whilst others require abstract reasoning abilities when considering module assessments. All significant discussions as well as individual assessment results were treated as strictly confidential and all ethical considerations were adhered to. All data related to the pre- and post-test were analysed and extrapolated from the assessments / assessment results by the psychologist.

5.2 Student Performance in OOP vs. Structured Programming

The student participants related to this study had no previous experience or exposure to OOP when this study commenced. The module that focuses on programming at the institution covers structured programming during the first semester of each academic year. The students only encounter OOP during the second semester.

To evaluate how the participants would comparatively fare between structured programming and OOP, a section of the pre- and post-tests were dedicated to questions indirectly covering the concepts of OOP. Data to represent the performance of the structured programming participants derived from their academic performance during the semester assessment of the programming module. The analysis of this section relevant to each test (pre and post) provided some interesting information. An analysis of the second section of the pre-test indicated that only

30% of the students from the control group and 32% from the experimental group respectively scored more than 40% for the OOP-related questions. Figure 5.1 presents the data graphically and Figure 5.2 offers an elaborated depiction of the results.

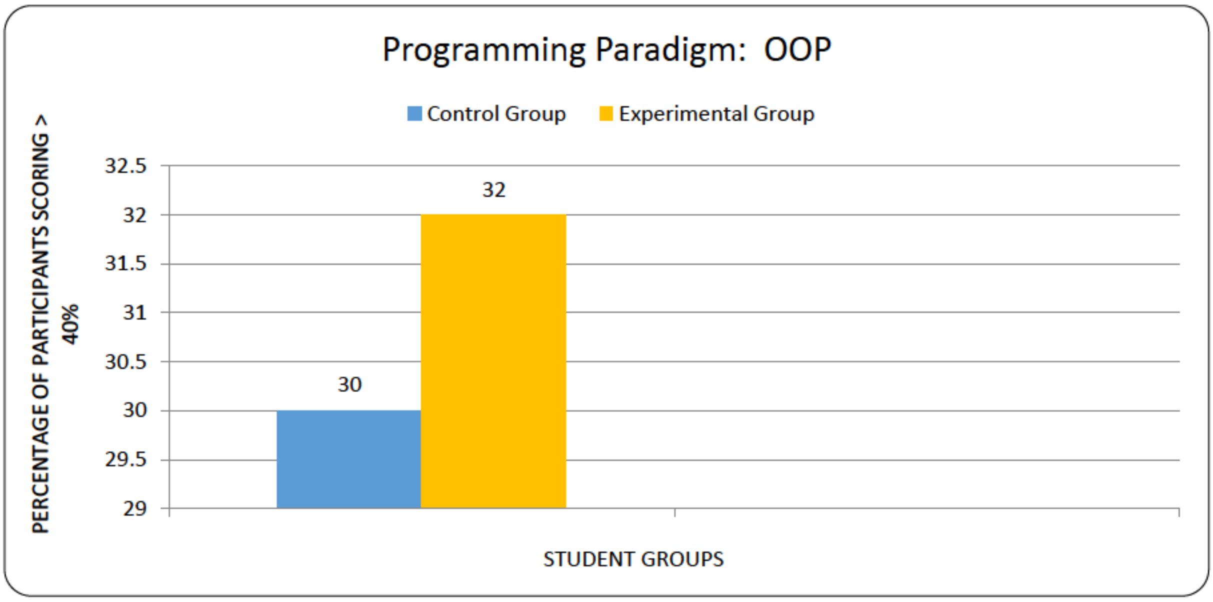

Figure 5.1: Percentage of participants of each group scoring more than 40% for the OOP-related questions of the pre-test

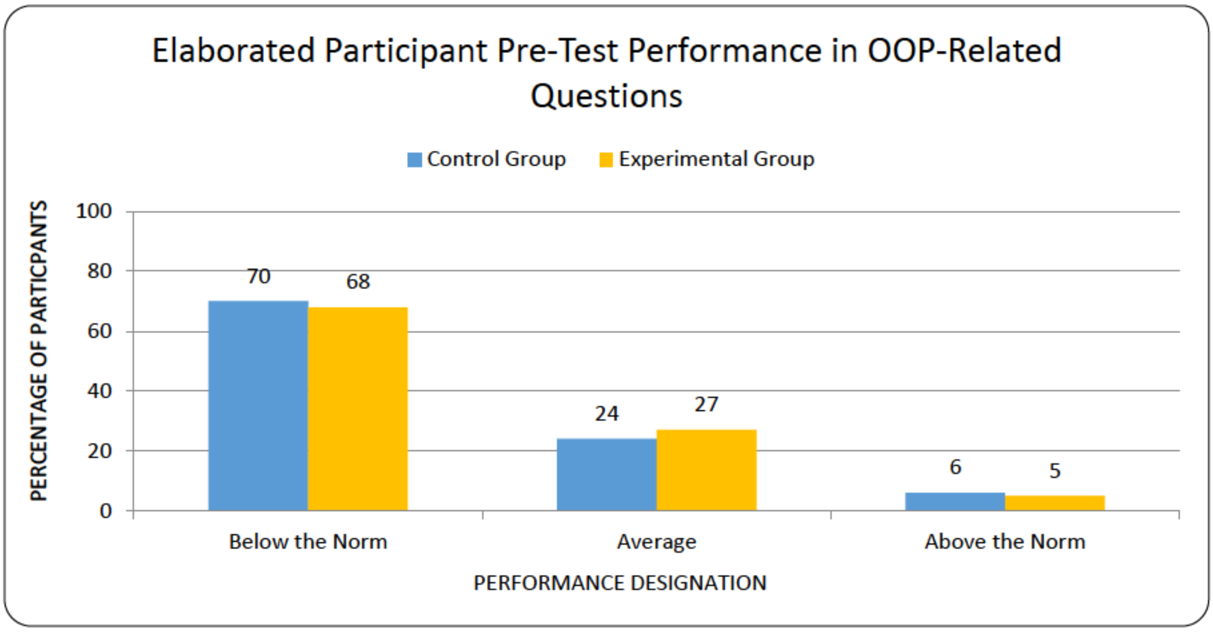

Figure 5.2: Elaborated group-performance of participants scoring more than 40% for the OOP-related questions of the pre-test

In contrast, 75% of the control group and 76% of the experimental group scored above 40% with regard to questions based on structured programming principles and concepts during the semester examination of the considered module respectively, as depicted in Figure 5.3.

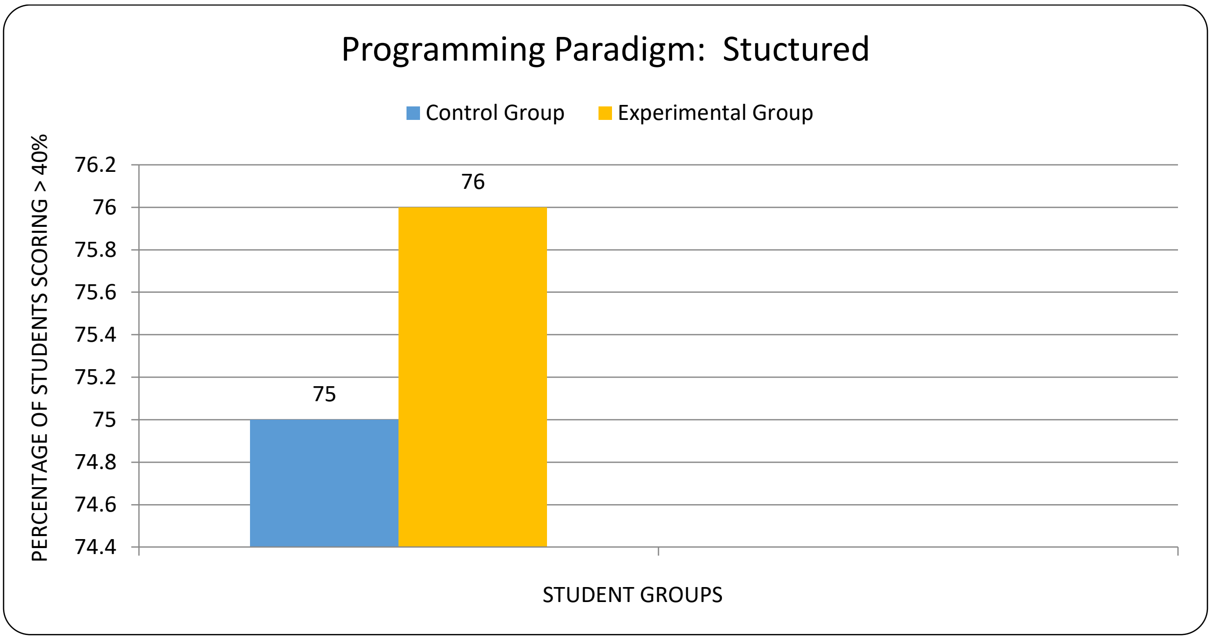

Figure 5.3: Percentage of participants of each group scoring more than 40% for the questions related to structured programming in the semester assessment

5.2.1 Control Group Reasoning Ability Before Engaging the Intervention

The reasoning ability, according to the objectives of the psychometric assessment (the first assessment), was divided into two categories: Verbal and non-verbal reasoning. Relevant to this study, the non-verbal reasoning abilities represents the abstract thinking or abstract reasoning abilities of the focus group. Figure 5.4 graphically represents the reasoning ability distribution of the control group.

Figure 5.4 suggests that 8% of candidates scored well below the norm of the group related to non-verbal reasoning (abstract reasoning). Of the candidates, 28% scored below the average when compared to the norm and 56% of the group tested on par with regard to non-verbal reasoning. In total, 8% of candidates scored above average and 0% well above average for non-verbal reasoning.

The researcher can therefore surmise that 36% of the participants scored below the norm in terms of abstract reasoning and only 8% scored above the norm in the same category. Comparatively, the test revealed that a greater number of students performed below average than above average when considering abstract reasoning ability. Also noticeable is that a greater number of students performed well below average in relation to those who performed well above average.

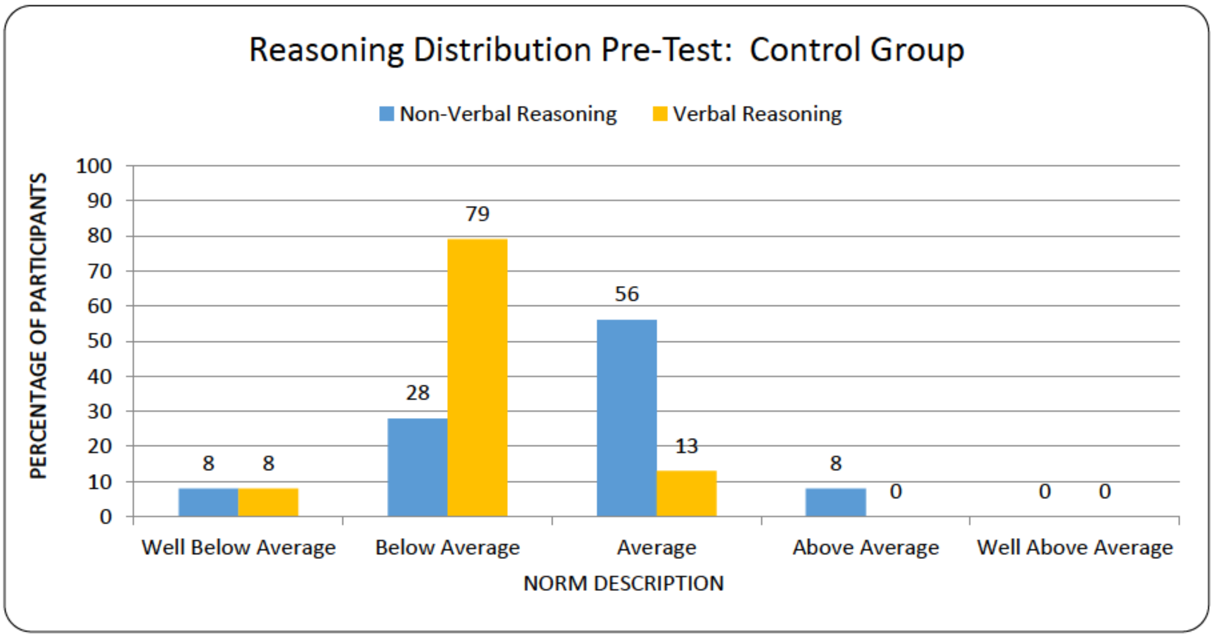

Figure 5.4: Reasoning distribution for pre-test results for the control group

5.2.2 Experimental Group Reasoning Ability Before Engaging the Intervention

The data analysis from the pre-test also communicated the verbal and non-verbal reasoning abilities of the participants. Figure 5.5 graphically represents the distribution of the verbal and non-verbal (which represents abstract reasoning capacity) reasoning ability of the experimental group.

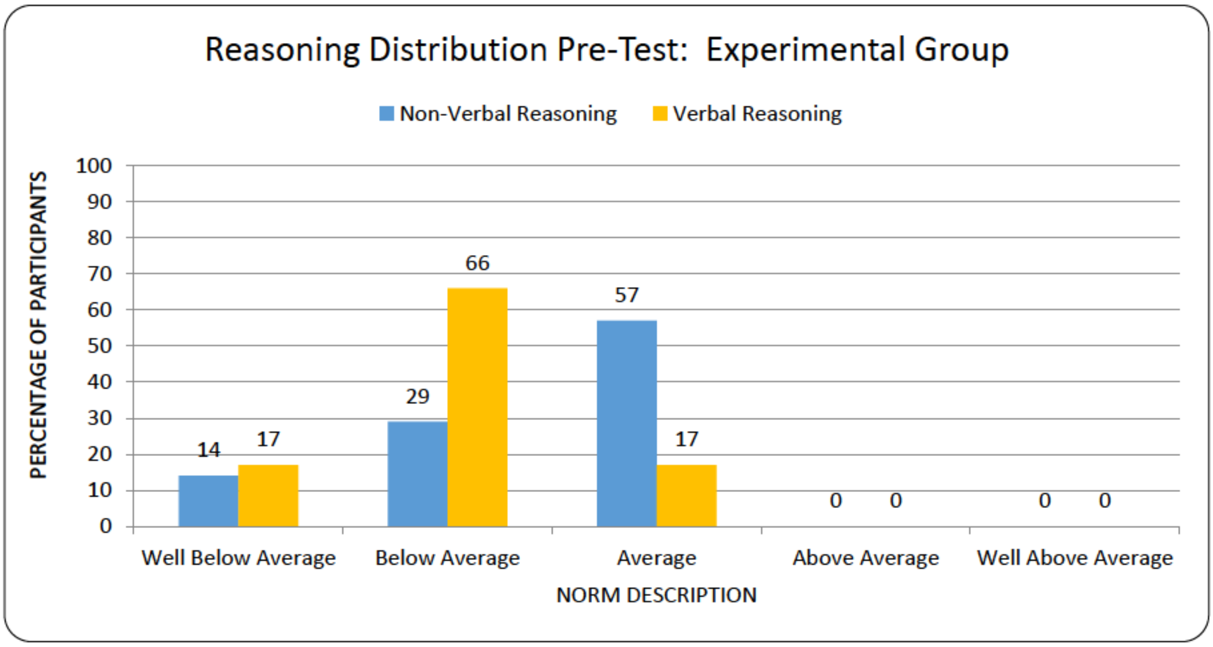

Figure 5.5: Reasoning distribution pre-test results for the experimental group

On average, approximately 43% of the focus group exhibited below average to well below average abstract thinking abilities with 0% of the experimental group exhibiting above average abstract thinking abilities. As exhibited in the figure, 0% of the experimental group performed well above average in terms of abstract thinking in relation to the norm.

5.2.3 Correlation of Findings

Table 5.1 provides an overview of the data collected from the two sections of the pre-assessment. The aim is to illustrate and compare the abstract thinking abilities, i.e. the non-verbal performance of the participants according to the psychometric assessment section's results with that of the student performance relevant to the OOP-related questions' results in the programming-related section of the pre-test.

The numeric data in Table 5.1 is presented categorically in terms of the percentages of the total number of participants of each group in this study.

	Rounded Control Group Sample in %	Rounded Experimental Group Sample in %	Performance Rating / Result
Pre-Test Section 1 Psychometric: The abstract reasoning abilities of the participants preceding any exposure to the intervention	36	43	Below to well below average
	56	57	Average
	8	0	Above to well above average
Total:	**100**		
Pre-Test Section 2 OOP-related: Performance of participants related to the OOP-based questions of the pre-test preceding any exposure to the intervention	70	68	< 40% (below the norm)
	24	27	40% to 60% (average)
	6	5	> 60% (above the norm)
Total:	**100**		

Table 5.1: Comparison between non-verbal psychometric performance and OOP assessment performance during the pre-test

The data in Table 5.1 relates the following: Approximately 92% of the control group scored well below to average in abstract reasoning abilities according to the psychometric section of the pre-test. On the other hand, 100% of the experimental group achieved the same performance for the named section. When the researcher considers the OOP-based questions of the pre-test and reviews the performance data relevant to these questions of the groups, the following is evident:

Of the total sample population, 69% received a mark between 0% and 39% for the OOP-related section of the pre-assessment. In the researcher's view, from a psychometric-rating perspective, this fragment is below to well below the norm. Approximately 25% of the total sample scored between 40% and 60% for the named section, which, if again viewed from a psychometric-rating perspective, relates to average performance. Finally, approximately 6% of the total number of participants scored more than 60% for the OOP-related question section of the pre-assessment, which relates to performance above the norm in terms of the psychometric-rating perspective.

At first glance, it appears that the data presented in table 5.1 and the subsequent scrutiny thereof supports the hypothesis as mentioned in Chapter 1 of this discourse. As a notary point, the hypothesis was stated in the mentioned chapter as being "*A custom software tool, specifically designed, developed, introduced and deployed to stimulate certain cognitive processes of the human brain, can improve students' abstract thinking ability and have a direct effect on students' performance in OOP when used for a determined period.*"

Further examination and testing is admittedly required at this stage of the study.

5.3 Post- Assessments Introduction

The experimental group engaged the intervention for 7 consecutive months, whilst the control group did not receive exposure to the intervention at all during this period. Admittedly, there were a small number of interaction days, totalling 23, in which the participants did not interact with the intervention due to institutional assessment periods and holiday periods, including public holidays. Fortunately, these missed interaction sessions were sporadically distributed over the total interaction period and no more than 3 consecutive interaction sessions were missed.

Both groups did a post-assessment consisting out of a psychometric assessment section as well as a section indirectly based on OOP-related concepts. This post-assessment was administered 8 months after the pre-assessment to ensure compliance with psychology standards and procedures that require a 6-month interval, at least, between the engagement of psychometric assessments for the same individual or group.

The same registered psychologist who administered and analysed the pre-assessment did the post-assessment.

5.4 Post-Assessments Discussion of the Data Collected

The post-assessments written by the two groups were scientifically analysed. Analysis, interpretation, and comparison of the data collected follow below.

5.5 Student Performance in OOP vs. Structured Programming

The results presented in Figure 5.5 depict the performance of the groups, both control and experimental, after the experimental group engaged the intervention for 7 months and after 8 months had passed between the pre and post-assessment of the groups.

Figure 5.6 illustrates an approximate 12% increase in the number of participants that performed above the norm in the experimental group related to the OOP section of the particular test. The control group exhibited close to the same performance in the same section when compared to the related performance in the pre-assessment.

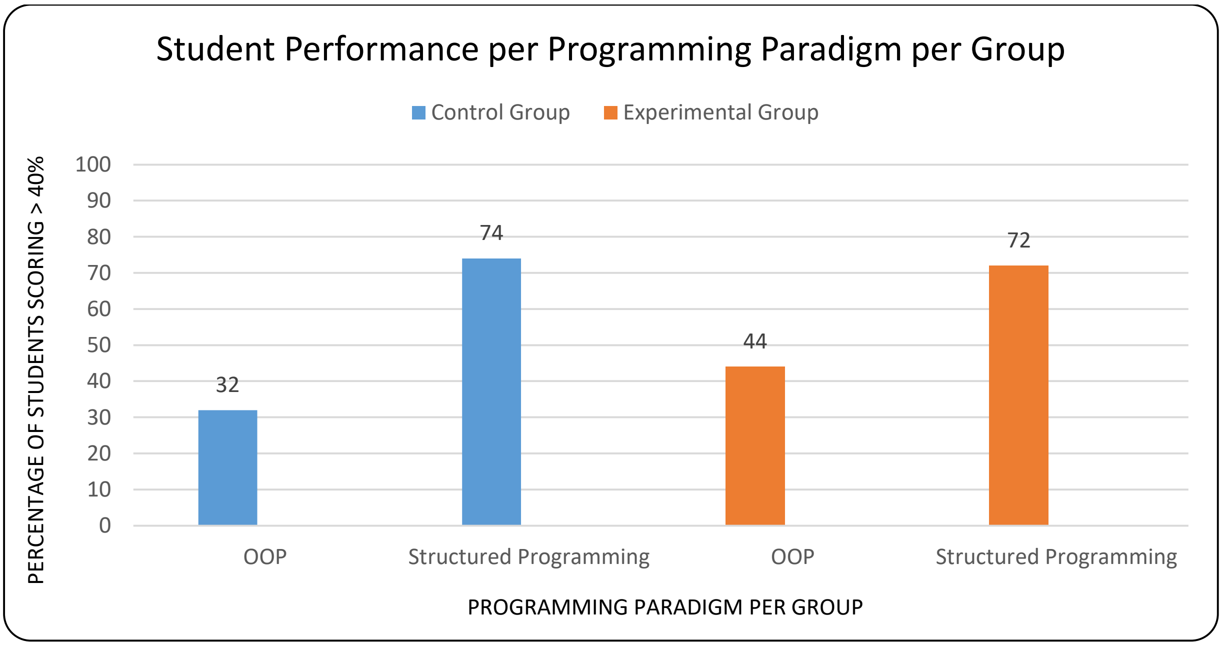

Figure 5.6: Participants scoring more than 40% in each tested programming paradigm in the post-test

The data from the pre and post-tests, related to the programming paradigms, is illustrated comparatively in figure 5.7. The abbreviation “SP” denotes the term “Structured Programming”.

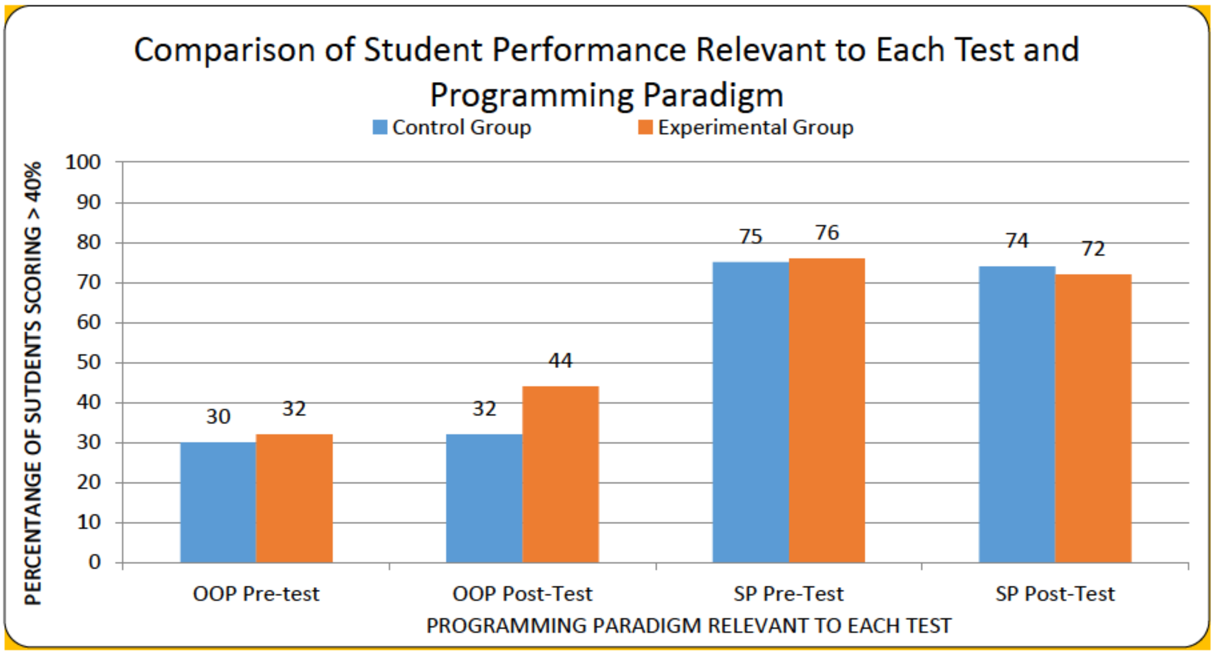

Figure 5.7: Comparing student performance related to OOP and Structured Programming relevant to pre- and post-tests

5.5.1 Control Group Reasoning Ability Post-Assessment

The same candidates from the control group who took part in the pre-psychometric assessment were asked to participate in the post-psychometric assessment as well. The post-assessment of this particular group occurred when the experimental group had concluded their interaction with the intervention. Figure 5.8 is a graphic demonstration of the reasoning ability distribution of the control group candidates.

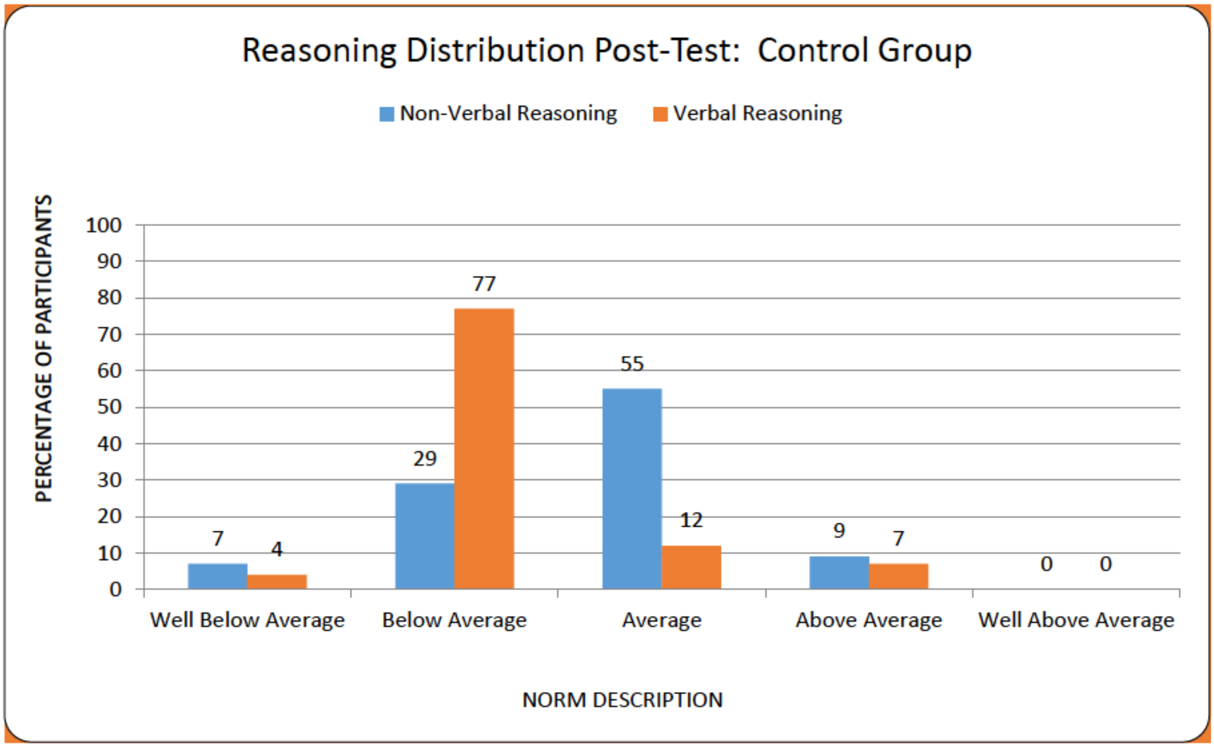

Figure 5.8: Reasoning distribution post-test results for the control group

Figure 5.8 demonstrations that 7% of the candidates scored well below the norm with regard to group related non-verbal reasoning (abstract thinking). As compared to the pre-assessment results for the control group 29% of the candidates scored below the average, which showed a 1% increase when compared to the relevant pre-test score of the group. Furthermore, 55% of the group tested on par with the norm on non-verbal reasoning. Finally, in total, 9% of candidates scored above average in the post-test as opposed to 8% of the candidates in the pre-test. The percentage for both the pre and post-assessment for students who performed well above average regarding non-verbal reasoning was 0%.

A 1% increase in the percentage of students that performed above average in terms of non-verbal reasoning is noticeable amongst the control group when comparing pre and post-test data.

Table 5.2 offers a comparative summary of the reasoning distribution data of the control group related to the pre and post-tests.

Performance Rating	% of Participants for Pre-Test	% of Participants for Post-Test	Increase (i) Same (s) Decrease (d)	% of i or d
Well below average	8	7	d	1
Below average	28	29	i	1
Average	56	55	d	1
Above average	8	9	i	1
Well above average	0	0	s	0

Table 5.2: Comparing the control group's reasoning distribution results for pre- and post-tests

Decreased values for the performance ratings labelled “well below average” and “below average” could be seen as progress, and increased values of the performance ratings labelled “average”, “above average” and “well above average” positive. Consider the column named “% of i or d”. The researcher can determine the overall progress or lack thereof through a simple calculation.

First, the researcher had to assign a variable name to represent the overall increase or decrease in performance. For the purpose of this study, the researcher assigned the variable name O_{id} to represent the overall increase or decrease in performance. If a performance value decreased for performance ratings labelled “well below average” and “below average”, the related value was viewed as positive, however, if a performance value increased for performance ratings labelled “well below average” and “below average”, the related value was viewed as negative. If a performance value increased for performance ratings labelled “average”, “above average” and “well above average”, the value is viewed as positive, however, if a performance value decreased for performance ratings labelled “average”, “above average” and “well above average”, the value is viewed as negative. The researcher also assigned representative variable names to the performance ratings as per the first column in the table that follows:

- Well below average = wba
- Below average = ba
- Average = a
- Above average = aa
- Well above average = waa

The researcher’s calculations follow:

$O_{id} = wba + ba + a + aa + waa$

$O_{id} = 1\% + (-1\%) + (-1\%) + 1\% + 0\%$

$O_{id} = 0\%$

The overall increase or decrease in performance figure on the part of the control group related to the post-test data for non-verbal reasoning is 0%, according to the calculations. This means that the control group tested the same as with the pre-test regarding non-verbal reasoning skills overall.

5.5.2 Experimental Group Reasoning Ability After Engaging the Intervention

The candidates who formed the experimental group also undertook the psychometric post-assessment. Figure 5.9 graphically outlines the experimental group’s data.

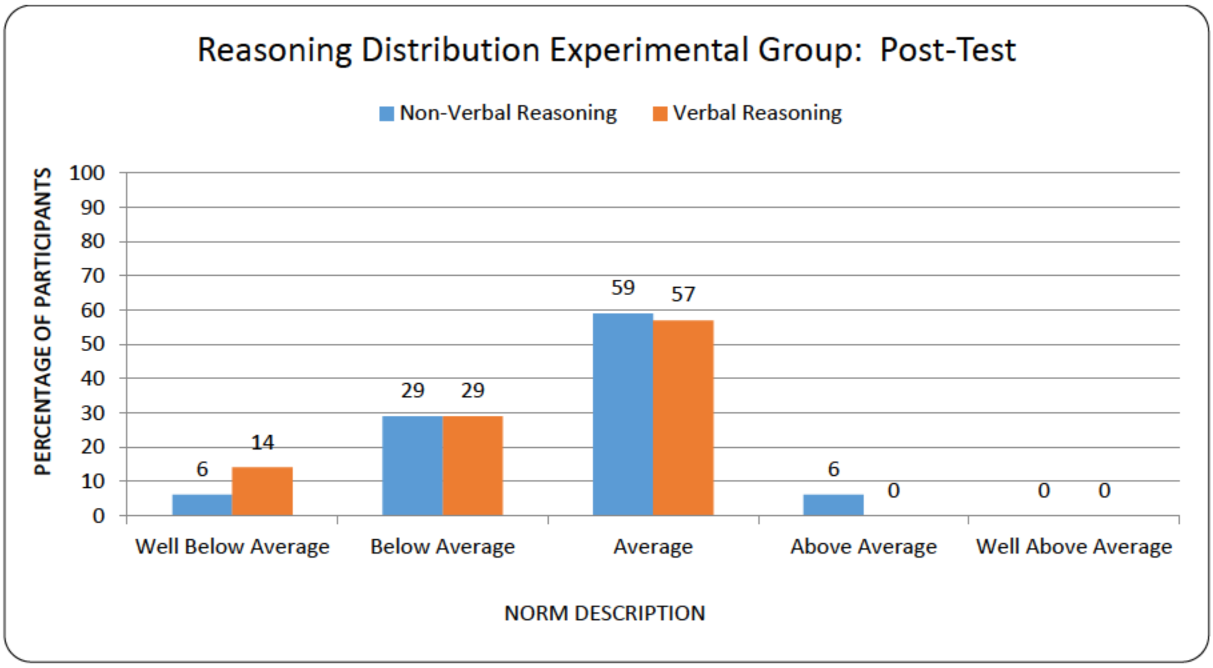

Figure 5.9: Reasoning distribution post-test results for the experimental group

Table 5.3 presents a comparative overview of the reasoning distribution statistics between the non-verbal performance of the experimental group relative to the pre and post-tests.

Performance Rating	% of Participants for Pre-Test	% of Participants for Post-Test	Increase (i) Same (s) Decrease (d)	% of i or d
Well below average	14	6	d	8
Below average	29	29	s	0
Average	57	59	i	2

Above average	0	6	i	6
Well above average	0	0	s	0

Table 5.3: Comparing the experimental group's reasoning distribution results for pre- and post-tests

The same argument as described in section 5.5.1 with regard to overall performance was applied to the data relevant to the experimental group. The subsequent calculation yielded the following result:

$O_{id} = wba + ba + a + aa + waa$

$O_{id} = 8\% + 0\% + 2\% + 6\% + 0\%$

$O_{id} = 16\%$

The overall increase or decrease in the performance figure on the part of the experimental group related to the post-test data for non-verbal reasoning therefore indicates a 16% overall increase, according to the researcher's calculations. This meant an overall increase of 16% in the experimental group's abstract reasoning ability when compared to the pre-test data.

5.6 Data Collected by the Intervention

The data that the intervention recorded during each interaction session was discussed in chapter 4. Even though the amount of data is extensive, a comprehensive discussion regarding, for example, how many times a student failed to answer a particular question correctly before getting it right, was not central to the research hypothesis or the research questions posed at the beginning of this discourse. The interaction with the intervention and the subsequent workouts were aimed at forming new neural pathways through the process of repetitive interaction.

As the workouts engage the cognitive processes related to abstract thinking abilities, it was anticipated that the newly formed neural pathways would be "abstract reasoning" pathways. To clarify the preceding statement: The study assumed that the newly created pathways would be of such a nature as to enhance the abstract reasoning abilities in the subjects that had engaged the intervention repetitively over a consecutive period.

The stimulation of abstract thinking abilities is not about getting certain questions right the first time or completing a game in a certain amount of time. The process is one of repetitive interaction with specifically designed content. As such, if a student got a particular question right the first time, it does not mean that a new neural link was magically created and that the particular person's abstract thinking ability has improved. It may simply indicate that the engaging party possesses a sufficient degree of abstract thinking abilities to answer the question correctly or to solve a posed problem, or maybe he/she just guessed right. Even if the particular engaging party successfully completes a whole workout level the first time, it does not mean that the abstract thinking abilities have improved. It just means that the relevant cognitive processes have been stimulated on a representative level (the level of the workout) and that the subject operated on a cognitive level that enabled him/her to complete the workout successfully. However, even if the workout was completed successfully on the first attempt, the cognitive processes related to abstract thinking abilities would still have been stimulated.

An argument could be made that progressively better results in participants' performance by successfully completing different workouts, on the different levels, is indicative of an improvement in abstract reasoning abilities in the subjects. The researcher would not necessarily disagree with such an argument but comprehensive research should be done to verify such assumptions that fall beyond the scope of this study.

The researcher contents himself with the end-result of this study. The data of the psychometric evaluation for non-verbal reasoning skills regarding the participants that engaged the intervention may confirm or contradict the research hypothesis. The intervention was developed to collect data for envisaged future use and deeper exploration, based on the outcome to this study.

5.7 Comparing Historic Institutional Performance

The researcher investigated the academic performance of first-year students by reviewing historic academic performance data of modules presented in the first year of study courtesy, of the relevant UoT. The data consisted of the final grade students received for 4 first-year modules from the year 2011 to the year 2015. For ethical reasons, no particular student's academic record was used, only the average marks obtained by a whole student group particular to the subjects of the relevant year of study.

By reviewing the historical academic performance of the first year student bodies over the 5-year period, the study has also attempted to draw conclusions between cognitive processes and academic performance. Mathematics, for example, is rooted in abstract concepts and consequently good academic performance in such a subject matter requires that the individuals possess well-founded abstract reasoning abilities, such as being able to generalize subject matters. Unlike mathematics, a subject like history does not lean heavily on an individual's abstract reasoning ability, but rather concrete cognitive abilities like retain and recall information.

The study reviewed the historic academic performance in terms of the final year grade received for the following reasons:

- OOP is only introduced in the second semester of the first year of study at the UoT. The OOP content covered during the semester is assessed during the examination period at the end of the semester. Therefore, to get a representative view of student performance related to OOP, the final average grade obtained by the relevant student group for the particular assessment for each year relevant to the study had to be reviewed. This data containing the final grade was only captured at the end of each academic year.

- The final-year grade, in many ways, represents the percentage of the content relevant to each module that the students had mastered. This final grade had to be reviewed in order to form a holistic impression of the first-year student body's academic performance.

The information relayed in figure 4.10 depicts the average final grades obtained by first-year students over a 5-year period for the relevant first-year modules. The data suggests that the average academic performance in modules requiring well-founded abstract thinking abilities within individuals is, on average, well below 50%. The subjects from the first-year IT module offerings at the particular UoT include Programming I – OOP and IT Mathematics I.

On the other hand, the module offerings that rely on other cognitive processes like recollection as opposed to, for example, generalization for good academic performance, exhibited better average academic performances over the same period. These module offerings included IT Essentials I and Information Systems I that consists largely of content that is pure theory and can be committed to memory by learning the content. The modules do not require specific creativity or problem-solving skills on the part of the engaging party.

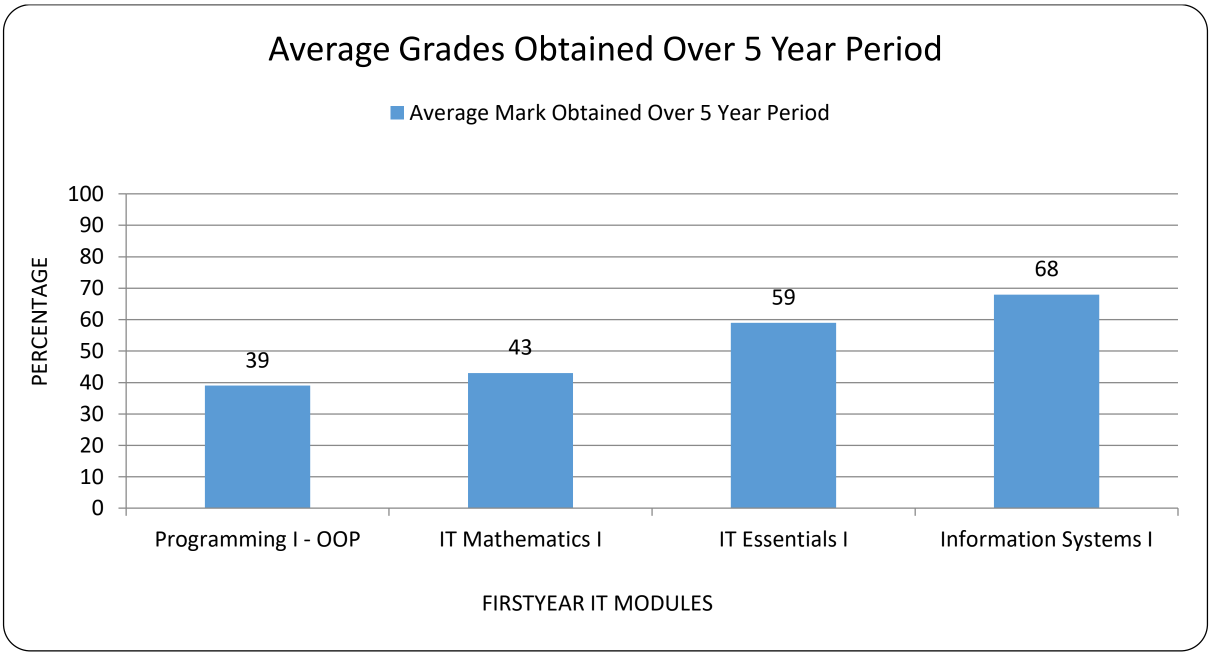

Figure 5.10: The average academic performance figures over a 5-year period of first-year IT modules presented at a UoT

5.8 Comparing Institutional Assessment Performance in OOP

First-year students of the UoT wrote an assessment that covered OOP during the third term. The participants of both groups formed part of the first-year student body of the UoT, therefore, their results were collected, recorded and submitted to the psychologist by the researcher. The experimental group had started their engagement with the intervention approximately one month prior to the particular assessment.

Both groups wrote a second assessment covering OOP five months later. By that time, the experimental group had been using the intervention for approximately six months. The following analysis indicates the average number of students, as a percentage, who exhibited a difference in academic performance when comparing the first OOP assessment performance with the second OOP assessment performance of each group respectively. The term *improvement* describes an improvement between the mark obtained for the first assessment and that of the second assessment. The term *no improvement* denotes no change in marks or a decrease in marks between assessments 1 and 2.

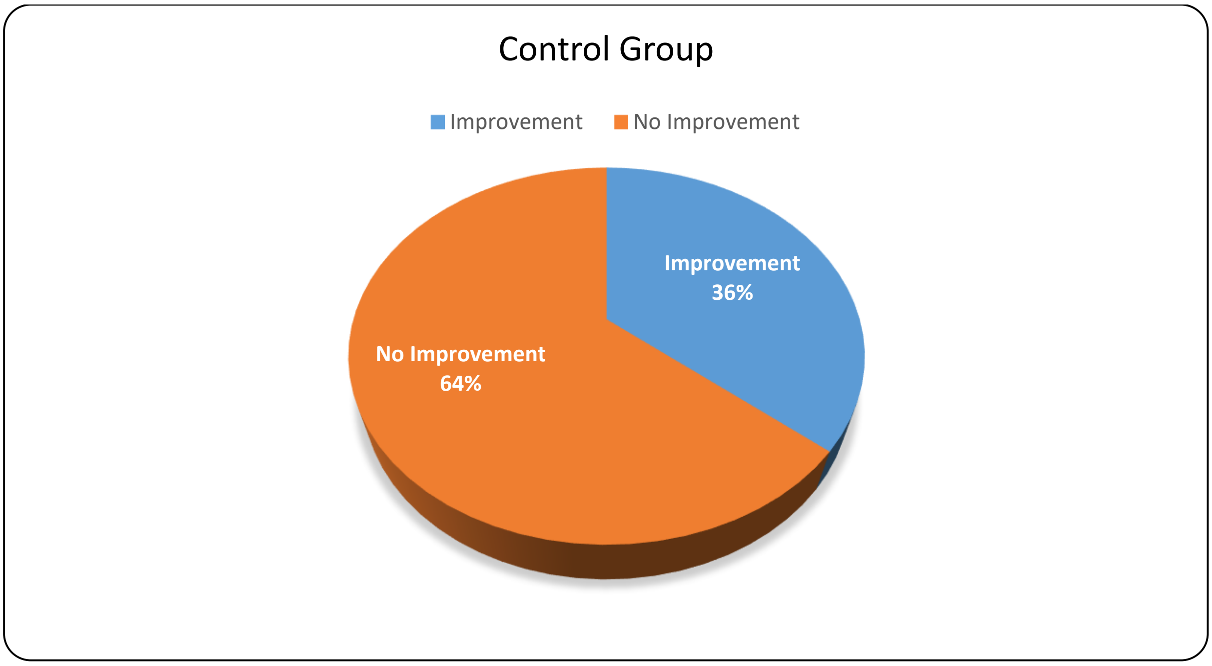

Figure 5.11: Control group: The percentage of students who improved/did not improve when comparing OOP assessment 1 and OOP assessment 2 marks

From Figure 5.11, which is related to the control group, one can clearly notice an approximate 36% of the students that exhibited an improvement in academic performance when considering OOP.

Figure 5.12 denotes the percentage of the number of participants of the experimental group that exhibited a difference between the academic performance of OOP assessments 1 and 2.

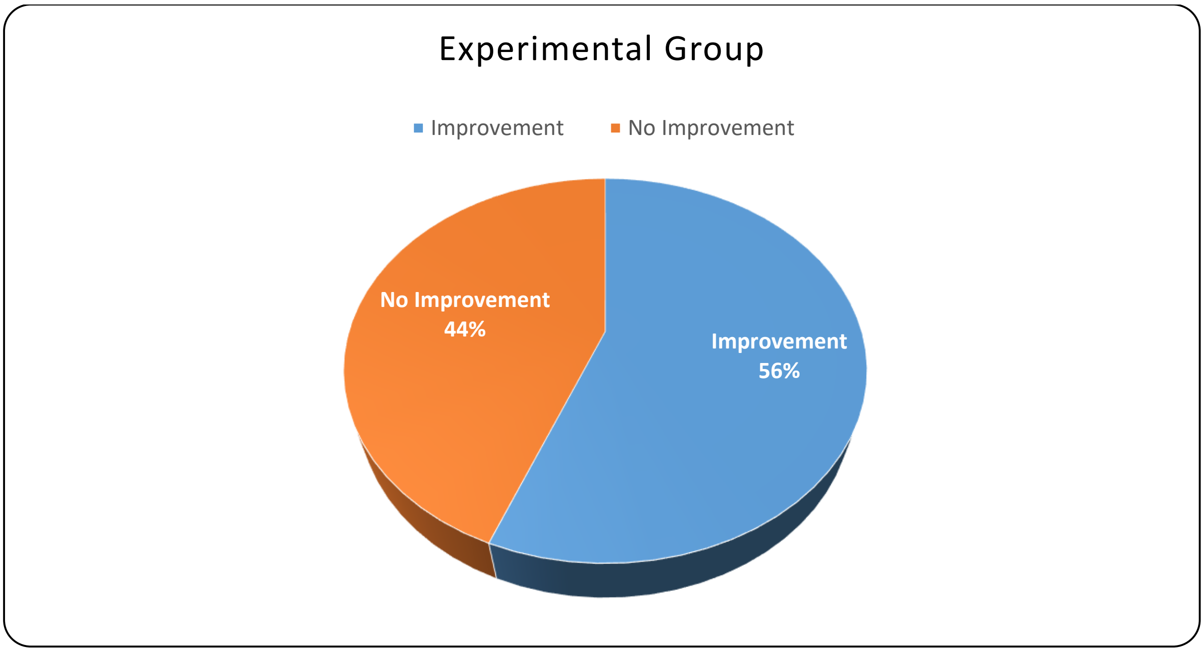

Figure 5.12: Experimental group: The percentage of students who improved/did not improve when comparing OOP assessment marks 1 and 2

As can be seen from the chart, on average 56% of the experimental group exhibited a noticeable improvement when considering the difference between the marks obtained by the experimental group for the first and second OOP assessments. Moreover, if one considers the improvement figures between the control and experimental group for the named assessments, it is evident that the experimental group showed an improvement, on average, in 20% more members than in the control group (56% and 36% respectively). This figure resonates with the average of 16% better performance in non-verbal reasoning ability of the experimental group as opposed to that of the control group in the post-psychometric assessment.

5.9 Statistical Analysis of the Questionnaire

With the aim to better understand the users and improve the intervention from a user-perspective, the researcher had to collect a subset of data and information from the members of the experimental group. This data and information relates to the:

- demographical nature of the participants;
- the opinions of the participants regarding the application;

- the participants' disposition; as well as
- an elaboration of the participants' thoughts and input regarding the intervention with reference to performance and usability aspects.

A questionnaire was compiled for distribution amongst members of the experimental group to collect as much data as possible. As mentioned in the previous chapter, the participants were allowed to remain anonymous whilst completing the questionnaire to encourage honesty when answering the related questions.

The psychologist who assisted with the psychometric evaluations of both the experimental as well as the control group, also statistically analysed and processed the data that originated from the questionnaire. This information/data was quite insightful and some of the answers will be looked at next. Figure 5.13 provides an overview of certain opinions of the users that engaged the intervention.

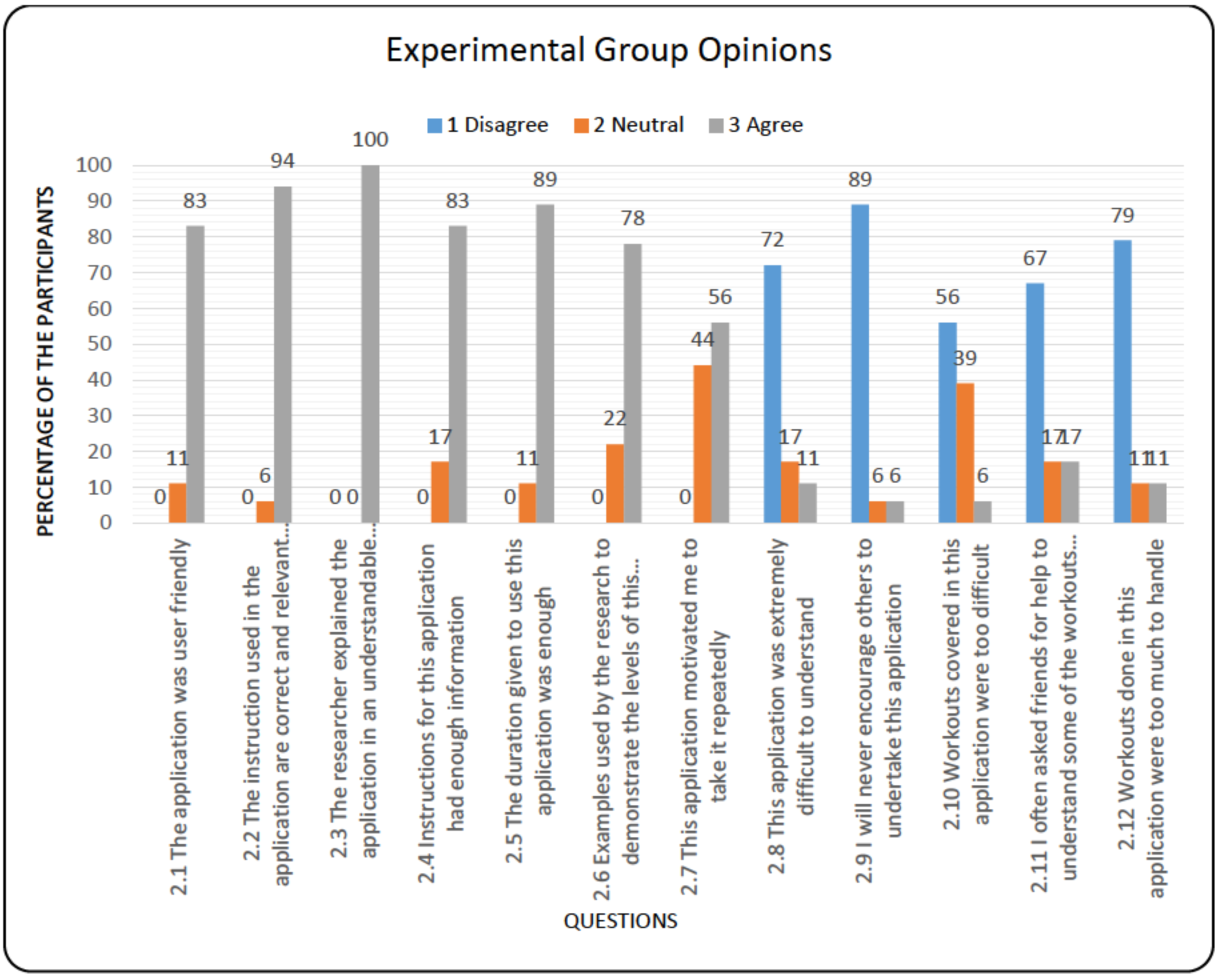

Figure 5.13: Experimental group opinions of intervention

With reference to 2.1 in figure 5.13, 83%, of the participants coped well with accessing the different parts of the user interface. With regard to 2.2, a collective 94% score indicates that participants easily understood the requirements or instructions in the different parts of the application. In question 2.3, 100%, agree that the reseacher explained the overall purpose of the application in a remarkable and outstanding manner. Question 2.4 shows that 83% of the application's instructions were enough for the participants to easily understand and navigate the different parts of the application.

Equally so, in question 2.5 it became apparent that most participants appreciated the overall duration to complete the workouts, as indicated by the collective score of 89%. A 78% score in question 2.6 indicates that participants appreciated the examples that were used by the researcher to demonstrate this application. With regard to 2.7, 56% of participants indicated not all participants were motivated during the interaction with the application.

Questions 2.8 and 2.10 respectively show that 72% and 56% of the participants disagreed that the application was difficult and 2.9 shows that 89% embraced the application.

Finally, question 2.11 and 2.12, respectively indicate that 67% of the participants disagreed that they requested help from their peers while engaging with the application, while 78%, disagreed that the workouts were too much to handle.

User's Thoughts and Input Regarding the Application

The questionnaire included four questions based on user's thoughts as well as inputs regarding the application as shown in Table 5.4.

Question number	User's Thoughts and Input Regarding the Application
4.1	Overall, what is your opinion of the value of the application?
4.2	Was the application fair to you, taking into account the type as well as number of workouts used?
4.3	Do you feel the application has improved your way of thinking? Please elaborate.
4.4	In your opinion, what needs to be added or removed to improve the application?

Table 5.4: User's thoughts and input regarding the application

- **Question 4.1**

  Participants revealed that the application inspired them to think hard and careful in any situation in order to provide a meaningful solution to the problem thereof.

- **Question 4.2**

  Although many participants provided answers to this question, a few left some blank spaces. Those who provided the answers indicated that on average the application was fair.

- **Question 4.3**

  Most participants explained that the application really developed and improved their thinking abilities a lot, and that they were able to think much faster than before they interacted with the application.

- **Question 4.4**

  Participants were asked for their opinions and recommendations as to what they thought needed to be added or removed in order to improve the application. Below are the ideas that participants put forward:

  - Add memo exercises;
  - Add maths exercises;
  - Increase time on exercises;
  - Add different activities to make it more interesting;

- Increase the number of questions;
- More options to accommodate different ability levels of students;
- More guidelines on how to approach the questions;
- Add puzzles;
- Split the application into three levels: easy, medium, hard; and
- Change the workouts daily. It becomes boring doing the same thing over and over.

5.10 Chapter Conclusion

Chapter 5 provided the reader with an overview of the analysis, presentation and deliberation of the data collected in this study. Furthermore, the pre and post-psychometric assessment data collected, for both the control and the experimental group, was comprehensively outlined. Additionally, the institutional assessment performance in OOP, both for the control group and the experimental group was critically analysed, presented and carefully delineated. The chapter concludes with an overview of both the software intervention results and statistical analyses from the questionnaire distributed to the experimental group members.

The following chapter provides final thoughts and conclusions based on the findings of the entire study.

CHAPTER 6

CONCLUSION

6.1 Introduction

The overall objective of this study was to investigate how a software tool could be designed and developed, specifically to stimulate certain cognitive processes in the users thereof. The cognitive processes the tool needed to stimulate related to abstract thinking ability to improve students' abstract reasoning and ultimately have a positive effect on their academic performance in OOP. Sub-questions related to this study were identified and are addressed within the confines of this chapter. For testing and exploration purposes, the intervention was deployed at a University of Technology in South Africa, focussing on first year IT students.

This chapter mainly focuses on answering the main research and sub-research questions based on the work done, the data collected as well as the interpretation of the subsequent analysed data. In addition, this chapter provides a summarized overview of the discourse, insights from the researcher and gives recommendations for future work.

6.2 Overview of the Study

Chapter 1 deliberated upon the research questions, aims and contribution towards the body of research. Furthermore, the research design and methodologies were outlined briefly and the motivation for the research addressed.

Chapter 2 provided a theoretical overview of relevant discussions by other researchers with the aim to explore relevant factors and concepts regarding abstract reasoning ability. In addition, the chapter focused on properly identifying, defining and understanding the aforementioned factors and concepts in detail. The exploration of the theory in this chapter also led to new insights regarding the brain processes related to abstract thinking ability and the inherent ability of the brain to form new permanent connections. Relevant theories explored in chapter 2 included

Piaget, who suggested the *development theory* that deals with things such as human behaviour and development, the abstract nature of mathematics as well as the role of the tools developed to teach OOP.

Chapter 2 also outlined existing software tools to address brain functions such as memory, reasoning, critical analysis and so forth, specifically delineated to the South African perspective. This chapter also touched on the importance of working memory with regard to abstract as well as computational thinking and explained the role and relevance of neuroplasticity processes occurring inside the human brain.

The last section of chapter 2 reflected on the theory, the importance, value as well as the use of the decision tree logical structure with regard to data classification as well as prediction purposes, whilst helping to manage the predetermined application rules in code modules.

The overview of one of the most significant dimensions of the research, namely research methodologies and the related empirical data collection methods, were discussed in Chapter 3. Followed by the predominant existing research approaches, specifically qualitative, quantitative and mixed approaches, as well as limited details with regard to action research for the sake of completeness.

This chapter helped the researcher to gain an understanding of, amongst other things, how to conduct experiments involving human participants. This included guidelines in the ITDP approach, of how to allocate participants to different groups (control and experimental) in such a way that the groups are equal in most respects.

Psychometric evaluations, in the form of GSATs, were also investigated as a data collection method related to gauging abstract thinking ability. The discussion of the empirical data collection methods and different research approaches led the researcher to gain the relevant knowledge to design a questionnaire in order to better understand the opinions, views and feelings of the users. The data collected via the questionnaire was about the overall functionality of the system as well as the interaction with the system. Chapter 3 also delineated the researcher's decision to follow a *mixed approach* with regard to an employed research approach.

Chapter 4 provided an overview of the empirical data collection tools and processes that were employed as well as insights into the development of the intervention.

The chapter continued by reviewing the psychological and psychometric methods and instruments available to gauge the abstract thinking abilities of individuals. Furthermore, important insights on how the participants were selected, differences between structured programming and OOP, the extensive review of the intervention, its constituents, the development thereof as well as the different code modules and what their functionality entailed, were provided.

The final section of chapter 4 provided an outline of the RDBMS that was employed as well as an overview of the questionnaire that was used to collect the data of the participants' perception about the intervention as mentioned in the paragraph above.

Finally, chapter 5 presented an overview of the overall data analysis, presentation and deliberation for the entire study. Moreover, the data of the pre as well as post psychometric assessments, both for the control group and the experimental group, were carefully outlined. Subsequently, the institutional assessment results of both groups, OOP and structured programming, were scrutinized, deliberated upon, analysed, compared, and presented.

The statistics regarding the OOP marks obtained between the experimental and control groups, were compared, depicted graphically, and explained in chapter 5. In conclusion, the chapter summarized the experimental group's feedback regarding the intervention, their perception, and feelings thereof in the form of analysed data from the questionnaire.

6.3 Revisiting Research Questions

This section revisits, reviews and attempts to answer the research questions through data collected and analysed during the course of the research. Different sets of the collected and analysed data can be used to address the different questions posed by the researcher at the inception of the study. Each question, as posed earlier in this discourse, is addressed separately to provide adequate attention to each question and proposed answer.

6.3.1 The Main Research Question

The main research question of this study was:

How can a software tool be developed and specifically designed to stimulate certain cognitive processes with the aim to improve students' abstract thinking ability and thereby have a positive effect on their performance in OOP?

To answer this question, the researcher had to understand the different aspects that this question involved. Therefore, the first important step was to engage, actively and extensively, the available literature related to the question. Subsequently, the theoretical review helped the researcher formulate sub-questions. The intention of the literature review was to gain useful theoretical knowledge and insights regarding various topics related or relevant to abstract concepts, abstract thinking abilities in general, useful programming constructs and algorithms that may prove useful in the development of the intended intervention. Important also, was to understand how brain processes were accessed and influenced in the past as well as how abstract thinking, or working memory processes, are stimulated.

The researcher also approached available experts in the field of psychology and ultimately employed such an expert with the aim to gain an even deeper understanding in the psychology behind the explored concepts of abstract reasoning and the related brain functions.

The expert used for the study and the researcher had several one-on-one meetings, prior to her inclusion. This process occurred before any software design and development was started or any experiments were designed or commenced. Psychological principles, and how one's ability to think abstractly could be developed, or stimulated were some of the issues discussed.

The expert employed in this study highlighted the fact that the level of abstract thinking that an individual possess relate directly or indirectly to the individual's level of ability to classify objects. An example of such would be the classification of a pen and paper and how it relates to each other as, for example, stationery. Other constituents of abstract reasoning ability include the ability to explain the functionality of objects as well as describe objects from memory, as perceived by the individual. In other words, it is the ability to break different objects up and classify them into basic parts with the aim of determining how the parts relate to one another and to assign, through conceptualization, differentiating, organizing, and attributing an overall structure or purpose to the objects in question.

The employed psychologist opined that an intervention, if properly developed and based on psychometrically proven instruments and theories, would be able to stimulate the brain's plasticity and as a result stimulate and possibly enhance the abstract reasoning abilities of the subjects. The psychologist further pointed out that literature confirms that the brain's plasticity (neuroplasticity) can be engaged via training and that with specific training, new neural pathways can be formed that may lead to improved working memory and other cognitive processes. As stated elsewhere in this research, neuroplasticity is the human brain's natural ability to change its structure, and form new connections throughout a person's lifespan, as a result of, amongst other things, one's life experiences, training, and so forth.

Drawing on literature and the employed expert's input, the researcher developed and incorporated different sets of games, exercises and abstract questions of varying difficulty into the intervention. These games, exercises, and questions focused primarily on the development of cognitive processes, like the working memory of the participants, as part of the stimulation process during the time the intervention was being done.

The researcher initiated a three tier architecture development process regarding the development of the intervention, whilst consistently consulting the psychologist to ensure that the incorporated content complied with psychometric standards/principles. As mentioned earlier, the intervention was developed specifically with the aim to activate the cognitive processes related to working memory. The results from the cognitive stimulation of the intervention would then be an indication of the development of abstract thinking abilities in the users thereof.

Indicators relevant to this study included a perceived overall improvement in academic assessment performance of the members of the experimental group in relation to similar performance of the control group and marks previously obtained for similar, previously engaged assessments of an OOP nature. The overall improvement in psychometric assessment results of the experimental group when compared to that of the control group and previous assessment performance also served as an indicator to the perceived success of the intervention's use.

When analysed, the data suggested the following:

- The number of members from the experimental group that exhibited an improvement when comparing OOP-based assessment after engaging the intervention for a set period amounted to 56%, averaging 20% more than that of the control group.
- An average increase of 12% in the OOP assessment marks was noted for the experimental group in relation to the academic performance of the first and second OOP assessments after engaging the intervention for the set period. The control group exhibited a 2% increase in assessment marks when considering the same assessments.
- After completing the psychometric post-tests, the experimental group exhibited an average improvement of 16% in abstract thinking ability when comparing the performance of a similar pre-test, whereas the control group exhibited no change in the average related to abstract thinking ability.

The question posed as the main research question therefore requires multi-dimensional consideration. The use of such an intervention should, at the very least, have a positive effect on the abstract reasoning ability of the users thereof, whilst a notable improvement in academic performance should be noticeable for OOP related subject matters too. Also, the constituents of working memory, such as the ability to classify objects can be trained. Furthermore, such a tool should incorporate the methodologies/principles proven to stimulate working memory in an efficient, pleasing way, and adhere to sound, scientifically based/developed assessment criteria and interface design.

The following sections focus on the sub-questions flowing from the main research question, and are answered with the aim to address the larger main research question.

6.3.2 Response to the first sub-question*: How is abstract thinking stimulated and developed?*

According to the literature investigated, one methodology that has proven to be effective in terms of practicing and developing abstract thinking and consolidating the ability to apply abstraction is formal modelling and analysis. Intervention incorporates psychometrically developed games, exercises and abstract questions in an attempt to transfer the theories from the pages of the literature to the intervention itself. These games, exercises, and questions require that the user solve problems through considering images in terms of concepts, generalizing the concepts, detecting patterns and relationships between objects, and finally, drawing logical conclusions from what is observed.

Each subsequent workout of the intervention consists of different games, exercises, and questions, or a varying combination thereof, to stimulate different brain functions related to abstract thinking and the different cognitive levels as explained earlier in the text (sub-section 4.10.1). All participant performance data is recorded by the intervention over the period of use. If a participant improves on the average performance over the period of use, it may indicate that the subject's abstract thinking ability is developing (sub-section 4.10.3).

Engaging in cognitive "warm-up" before undertaking any strenuous cognitive stimulation or exertion can be beneficial when considering the cognitive processes and the establishment of new neural connections and pathways (section 4.10.2). A warm-up section therefore also makes up part of the intervention.

The literature study indicates that although the brain can change itself physically as well as functionally during the learning process, at any age and in a number of ways, there are limits to how much the brain can change. According to Psychological and Neurological Science professionals, the fact that there are limits to how much the brain can change correlates to the fact that human abstract thinking abilities can be stimulated up to a certain stage.

6.3.3 Response to the second sub-question: *What evaluation instruments or methods for empirically evaluating abstract thinking ability currently exist?*

The General Scholastic Aptitude Test (GSAT), developed to revise and improve upon previous intelligence and aptitude testing employed in South Africa, is unique to the country. In general, GSAT assesses the general scholastic aptitude of South African learners and is divided into three overlapping levels, namely Junior, Intermediate, and Senior (section 4.5).

A standard GSAT is used to assess, amongst other things, the verbal and non-verbal skills of the person being assessed. Non-verbal skills are of particular interest to this study as they signify/represent the abstract thinking abilities of the person assessed (section 4.5).

A standard GSAT assessment formed part of the research evaluations to evaluate both the non-verbal as well as the verbal skills of a control and an experimental group. To quantify the abstract thinking abilities of the participants, the study employed the psychometric lens (section 4.5).

6.3.4 Response to the third sub-question: *Of what should an IT tool with the aim to engage and develop abstract thinking ability comprise?*

Since this sub-question relates closely to the main research question of the study, some of the psychometric instruments, incorporated into the intervention, have already been explained earlier in this chapter in response to the main research question. Nevertheless, some constituents, like warm-up exercises, will be discussed.

A dedicated repository for warm-up games and exercises, that progressively stimulate the relevant cognitive processes as per the psychometric recommendations without exerting the mind, were incorporated into the intervention development (section 4.10.1). One example of such an incorporated warm-up exercise is the “connect the 9 separate dots by making use of only four consecutive lines without lifting the pen and without tracing any line more than once” exercise. This game engages some of the critical cognitive processes linked to abstract thinking (section 4.10.2).

Dedicated code modules were created and presented as games, exercises or abstract questions and incorporated content that addressed and stimulated aspects of abstract reasoning ability. These aspects are as follows:

- Critical analysis;
- Classification of separate, but related objects;
- Description of objects from memory;
- Description of objects based on perception;

- Relation and explanation of functionality.

An IT tool should include all of the constituents mentioned in this section whilst addressing the relevant cognitive processes through the representation of the constituents. In addition, content should be aesthetically pleasing and engaging, in a fun way. The analysis of the questionnaire revealed the latter, relevant to the exploration of the user's opinions of various aspects of the intervention, such as interaction design.

6.4 Summary of the Research Contributions

This section focuses on the larger contributions of the study to the general corpus of knowledge.

The contribution of the study resulted from the adoption of a mixed-method approach. This methodology involves collecting, analysing, and integrating quantitative as well as qualitative research in a single study or a longitudinal program of inquiry. The combination of both qualitative and quantitative research provided broad understanding of a phenomenon of interest better than either research approach alone could achieve.

The primary contribution of this research is twofold:

1. The successful development of an Information Technology Software Intervention that stimulates and develops cognitive processes and parts of the brain responsible for abstract thinking ability. The psychometric and assessment evidence that was derived from the data indicated the success of the intervention and its use over a relatively short period. The use of the intervention led to an academic performance improvement in object-oriented programming results and working memory ability for students from a UoT. The researcher expects an even greater improvement with prolonged use of the intervention.
2. The researcher was able to explore, identify, list and elaborate upon a body of knowledge that prospective developers of an IT intervention that aims to address certain cognitive abilities, may consider.

A secondary contribution could be the unique manner in which the South African GSAT assessment principles have been incorporated and digitized as part of the intervention. Moreover, the games and exercises developed from the GSAT principles and incorporated as tools to stimulate cognitive processes, are noteworthy. This, in the view of the researcher, emphasizes the South African context within and of the intervention.

Furthermore, this study has found that the inherent ability of the brain to form new neural connections, termed neuroplasticity, can be exploited through specifically designed technology to promote the development of a subject's abstract thinking ability. This can ultimately lead to improved academic performance in subjects rooted in abstract concepts and requiring good abstract reasoning skills to perform adequately.

Another contribution is the integration and application of knowledge of most of what first-year Information Technology students are required to learn during their studies at the particular UoT. The training and stimulation of the students', using the intervention, abstract thinking abilities, proved to be of great service to the students in this respect. In that light, and maybe from a more personal perspective, the researcher considers the enhanced academic performance of the members of the experimental group as both a triumph and a notable contribution.

6.5 Implications for Further Research

Many concepts related to OOP require students to exhibit a high level of abstract thinking abilities in order to process higher-order mental activities. Although the intervention proved successful with regard to the set objectives within the confines of this study and case environment, this section explores possible further research avenues after the completion of this study.

A larger and more diverse case area and a more diverse group of users may be beneficial in terms of the future deployment and use of the intervention. This is especially true if one aims to generalize the results obtained in this study, or at least compare the results on a larger scale.

It may also be beneficial to make use of technology such as Magnetic Resonance Imaging (fMRI), magnetoencephalography (MEG) or electroencephalography (EEG) to track and depict the brain activity of a user during a session in which the intervention is used. This may enable the development of more focused and efficient software technology to stimulate and develop abstract reasoning abilities.

Users may also benefit from the use of the intervention in a mobile format. The intervention may be developed into a mobile application, whilst incorporating all of the key features of the desktop version. Accessibility issues can be addressed through making use of mobile platforms and may lead to enhanced usage time due to the ready availability of the device.

More versions of games, exercises and abstract questions may be considered as well, as the number of unique combinations of content stimulating specific cognitive processes is limited in the current iteration of the intervention. This may lead to boredom when used over time, or worse, the user may engage cognitive processes associated with recall and recognition, rather than working memory, thereby defeating the purpose of the intervention.

Answers provided via the questionnaire that was completed by the experimental group, provided the following insights regarding enhancing the application and are listed here as future work to be considered. The suggestions are, but not limited to the following (section 5.9, Statistical Analysis of the Questionnaire):

- Addition of memorandum feedback/interactive answer explanations;
- Addition of maths exercises;
- Increase time to complete exercises
- Addition of different activities to make it more interesting;
- Increase the number of questions;
- Addition of puzzles.

Although software intervention primarily focuses on stimulating abstract thinking abilities with the aim to improve performance in OOP, it can also be applied to support students in other programming paradigms, such as Procedural Programming and other areas such as IT Mathematics that require abstract thinking skills. However, due to the particular complexities of OOP, the intervention focuses strongly on a holistic view where different kinds of decisions require abstract thinking skills, especially in programming classes. A more generalized version of the application may be adapted from the initial version and deployed in secondary learning institutions and its effects on abstract reasoning skills amongst learners carefully monitored. This can be done with the aim to develop and record abstract reasoning skills from a younger age.

Finally, it may also prove useful to monitor the progress of the members of the experimental and control groups throughout their studies, especially with regard to academic performance in programming subjects. The data collected may indicate inadequacies in the current design of the intervention as well as expose issues regarding the longevity of the effects related to the use of the intervention or lack thereof.

6.6 Chapter Conclusion

The ultimate objective of this study was to investigate the possibility of developing an IT tool with the aim to affect, positively, the abstract reasoning ability of its users. The researcher also aimed to gauge the performance and impact of such an intervention on the abstract reasoning abilities of first-year students with the aim to improve their academic performance in OOP. This was because a clear challenge existed in this regard amongst first-year students of a particular UoT.

OOP concepts and principles are highly abstract in nature. The researcher therefore hypothesized that, if the abstract reasoning ability of an individual studying OOP could be enhanced or developed, said individual would be able to perform better academically in subject matters regarding OOP.

This discourse explored and tried to understand theoretical and practical concepts related to abstract reasoning ability, and the stimulation and development thereof. Many interesting approaches, principles and theories, such as neuroplasticity, Piaget's levels of development, the GSATs and other psychometric principles and tools were incorporated into the intervention. These concepts and principles were developed into games, exercises and abstract questions with the aim of stimulating the abstract thinking ability of those exposed to it.

The intervention was subsequently tested and scrutinized on various levels to explore and investigate if the design was sufficient in terms of content and content presentation, rigorous as well as having the desired impact on the users thereof in terms of developing their abstract reasoning ability. The interaction of the intervention commenced after a subset of participants were divided into a control and experimental group respectively and their non-verbal reasoning, or abstraction skills, were tested through the GSATs. The interaction period lasted 5 months and both groups partook in the GSATs again after the interaction period was completed.

While the interaction period was underway, the researcher investigated relevant student performance of other subjects that use abstract concepts, such as IT Mathematics. The historic results of these subjects, or modules, confirmed that there was a trend/relation regarding the student performance of fist year students and subjects that was abstract in nature. Also, the researcher recorded the results of an OOP based assessment of the members of both groups when the interaction period commenced and concluded.

The results of the GSATs as well as the second OOP assessment confirmed that the members of the experimental group fared better than those of the control group. The researcher can therefore assume that the methodology developed, followed and applied to the development of an IT tool with the aim to positively influence abstract reasoning abilities through its use, as shared in this discourse, was successful. Furthermore, the constituents that make up the intervention in the form of content and as developed from literature, experimentation and input from qualified psychology and psychiatric professionals, proved not only to be beneficial to the users, but effective in stimulating and developing the cognitive processes related to abstract reasoning skills within the users. The aforementioned fact is supported by evidence collected through scientifically recognized empirical data collection methods and the professional scrutiny thereof.

The major contribution of this study is the identification, conceptualization and development of specific types of instruments from and based on psychological principles. The successful integration of these instruments into the larger intervention that proved to have a positive effect on the abstract reasoning abilities of the subjects, can also be highlighted once more.

The findings of this study indicate that the intervention has delivered on what was anticipated and all of the questions posed when this study was initiated, answered adequately. More importantly, the researcher himself emerged a changed person, on many levels, at the conclusion of this study, having worked hard, pushed the boundaries of what was thought possible within the relevant realm of existence and ultimately succeeding in realizing the objectives and learning a considerable amount about the related content, development, the research process and himself.

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8 Appendices

21 Gardenia Street
Riebeeckstad
Welkom
9459

29 February 2016

Dear Participant

My name is **Moabi Saul Kompi** and I am a registered Postgraduate Master's student at the Central University of Technology, Free State, Bloemfontein Campus.

The title of my research is **"An Information Technology Instrument to Facilitate the Development of Abstract Thinking for Object-oriented programming".** The purpose of this letter is to kindly request you to participate in this research study, by voluntarily undertaking a psychometric test.

I wish to confirm the following before you commence with completion of the test:

- Any participant is more than welcome to withdraw from completing this test any time if the relevant participant feels uncomfortable with the completion of the test in any way.
- The aim of the study will be made clear to any and all participants before the named test will commence.
- The confidentiality of this survey is guaranteed and participants will not be requested to provide any personal information beyond their names, surnames and gender.
- The results / outcomes, including copy of the completed research report of this study, will be made available to any participant upon reasonable request.
- Should a participant encounter any ambiguity regarding this test or have any enquiries with regard to this test, please feel free to contact me on the following: mkompi@cut.ac.za. I will respond as soon as I am able to do so.

Your time and honest response is highly regarded.

Thank you

____
Name and Surname of participant

Mr MS Kompi

____
Signature of participant

____
Date

Appendix A: Consent letter

21 Gardenia Street
Riebeeckstad
Welkom
9459

02 February 2016

Dear Participant

My name is **Moabi Saul Kompi** and I am a registered Postgraduate Master's student at theCentral University of Technology, Free State, Bloemfontein Campus.

The title of my research is **"An Information Technology Instrument to Facilitate the Development of Abstract Thinking for Object-oriented programming".** The purpose of this letter is to request kindly that you participate in this research study by voluntarily completing the attached survey.

I wish to confirm the following before you start completing the attached questionnaire:

- You are more than welcome to withdraw from completing this questionnaire any time if you do not feel the need to continue with the completion.
- Your involvement will help enhance students' performance with regard to the above-mentioned topic and assist them to complete their studies.
- The confidentiality of this survey is guaranteed and you will not be requested to provide any personal details.
- A copy of the completed report will be made available to you upon reasonable request.
- Should you encounter any ambiguity regarding this questionnaire or have any enquiries with regard to its completion, please feel free to contact me on the following: mkompi@cut.ac.za. I will respond to such request at my earliest convenience.

Your time and honest responses are much appreciated.

Thank you

Mr MS Kompi

Appendix B.QP1: Questionnaire consent letter and also questionnaire page 1

Questionnaire

Respondents of this questionnaire are asked to answer the questions in this survey with utmost honesty. The analysis of this questionnaire will assist in the improvement of an Information Technology artefact, thus the information concerning this questionnaire is very important.

Section 1: Demographic Information

Please mark your response with a cross (X) where appropriate. E.g.

Smoke	Y		N	**X**

1.1	**Gender**	Male		Female	

1.2	**Age Range**	Under 20		20 - 29		30-39		40-49		50 and over	

1.3	**Math grade 10 - 12?**	Yes		No	

1.4	**If the answer above is yes then make a cross in the appropriate block**						
	Maths Rating	1-3		4-6		7-8	

1.5	**Number of years at CUT**	Less than 1 year		1-2		3-5	

1.6	**Your nationality**	Traditional African	Caucasian	Other

Appendix B.QP2: Questionnaire page 2

Section 2: Opinions Regarding the Application Software

In this section, information about Abstract thinking as application is required. After careful consideration with regard to indicators, the researcher decided to use indicators deemed applicable for this study. The following are indicators, please show the extent to which you agree or disagree by placing a cross (X) in the appropriate block 3 = (Agree), 2 = (Neutral), and 1 = (Disagree).

2.1	The application was user friendly	Agree	3	2	1	Disagree
2.2	I enjoyed using the application	Agree	3	2	1	Disagree
2.3	The instructions used in the application are correct and relevant to the particular task of the application	Agree	3	2	1	Disagree
2.4	The researcher explained the application in an understandable manner	Agree	3	2	1	Disagree
2.5	Instructions for this application had enough information	Agree	3	2	1	Disagree
2.6	The duration given to use this application was enough	Agree	3	2	1	Disagree
2.7	Examples used by the researcher to demonstrate the levels of this application were good	Agree	3	2	1	Disagree
2.8	This application motivated me to take it repeatedly	Agree	3	2	1	Disagree
2.9	This application was extremely difficult to understand	Agree	3	2	1	Disagree
2.10	I will never encourage others to undertake this application	Agree	3	2	1	Disagree
2.11	Workouts covered in this application were too difficult	Agree	3	2	1	Disagree
2.12	I often asked friends for help to understand some of the workouts in this application	Agree	3	2	1	Disagree

Section 3: Participant Disposition

3.1	I attended classes for this application regularly	Agree	3	2	1	Disagree
3.2	I answered every single workout honestly	Agree	3	2	1	Disagree
3.3	I was always in a hurry to finish all the workouts	Agree	3	2	1	Disagree
3.4	I usually prepared myself before undertaking the application	Agree	3	2	1	Disagree
3.5	I sometimes had, amongst other things, personal problems while undertaking the application	Agree	3	2	1	Disagree
3.6	The application helped me to think differently, accurately and fast, amongst other things	Agree	3	2	1	Disagree
3.7	I understood the overall meaning for undertaking this application	Agree	3	2	1	Disagree

Appendix B.QP3: Questionnaire page 3

Section 4: User's Thoughts and Input Regarding the Application

4.1 Overall, what is your opinion of the value of the application?

4.2 Was the application fair to you, taking into account the type as well as number of workouts used?

4.3 Do you feel the application has improved your way of thinking? Please elaborate.

4.4 In your opinion what needs to be added or removed to improve the application?

Thank you for your valuable time and participation. Your views are much appreciated

Appendix B.QP4: Questionnaire page 4

Central University of Technology, Free State

2016-08-04

TO WHOM IT MAY CONCERN

STUDENT: M KOMPI
STUDENT NO: 9613056

This letter serves to confirm that the statistics for the Faculty of Engineering – Welkom Campus for students who graduated in 2013, 2014 and 2015 is a true reflection. It was handed to the student by the undersigned, Mrs EM Kruger, Assistant Assessment Officer – Welkom Campus as part of his research for his M Tech Information Technology qualification.

Kind regards

EM KRUGER
ASSISTANT ASSESSMENT OFFICER
WELKOM CAMPUS
Tel: 057 910 3665
Fax: 057 910 3677
E-mail: ekruger@cut.ac.za

Central University of Technology Free State
2016 -08- 04
EXAMINATION SECTION
WELKOM CAMPUS

Mothusi Road, Thabong, Welkom, South Africa, 9459 • www.cut.ac.za
PO Box 1881, Welkom, South Africa, 9460

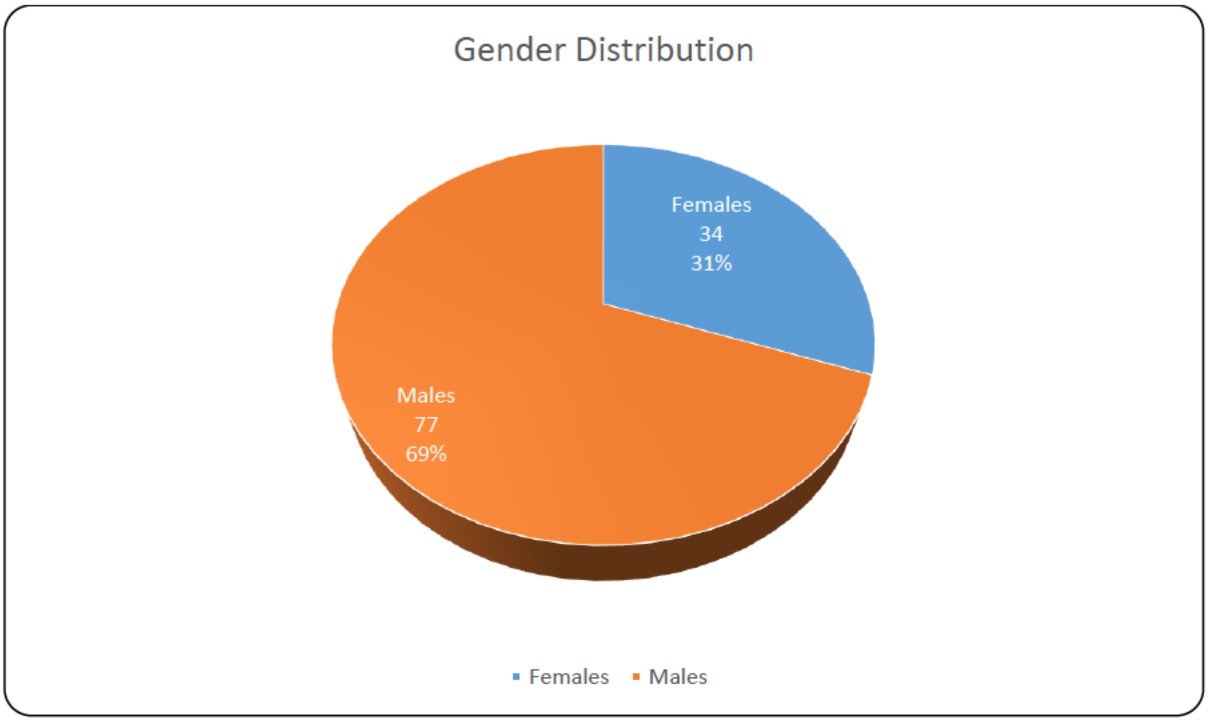
Appendix C: Confirmation letter

```
private void frmAbstractReasoningExercise5_FormClosed(object sender,
FormClosedEventArgs e)
{
    string totalCorrect, totalIncorrect;
    totalCorrect = String.Format("{0}:{1}:{2}:{3}", ex5Q11Correct, ex5Q12Correct,
ex5Q13Correct,ex5Q14Correct);
    totalIncorrect = String.Format("{0}:{1}:{2}:{3}", ex5Q11IncorrectCount,
ex5Q12IncorrectCount, ex5Q13IncorrectCount,ex5Q14IncorrectCount);
     DataAccess.Insert(TimeDate.StartDate(false), TimeDate.StartTime(false),
TimeDate.GetStopTime(), TimeDate.GetDuration(), "11:12:13:14", totalCorrect,
totalIncorrect, frmMainMenu.UserName, frmMainMenu.UserPass);
     DataAccess.CloseConnection();
     frmExercisesSwitchBoard switchBoard = new frmExercisesSwitchBoard();
            switchBoard.Show();
}

private void frmAbstractReasoningExercise5_Load(object sender, EventArgs e)
{
    if (countMessages == 0)
     {
         string instruction = "For this workout answer as many questions as you can
         in 4 minutes." + "\nClick button to the right which corresponds to correct
         answer." + "\nYou will be allowed to proceed to the next question," +
         "\nonly if you have selected the correct answer.";
         MessageBox.Show(instruction, "Workout 5 Instructions");
         countMessages++;
     }
}

#region ClickEvents
#region GroupBox1Events
private void btnEx5Grp1A_Click(object sender, EventArgs e)
{
    ex5Q11IncorrectCount++;
}

private void btnEx5Grp1B_Click(object sender, EventArgs e)
{
    ex5Q11IncorrectCount++;
}

private void btnEx5Grp1C_Click(object sender, EventArgs e)
{
    ex5Q11Correct = 1;
    MessageBox.Show("Your choice is Correct!", "CONGRATULATIONS!");
    grpEx5ARQ12.Visible = true;
    grpEx5ARQ11.Enabled = false;
}

private void btnEx5Grp1D_Click(object sender, EventArgs e)
{
    ex5Q11IncorrectCount++;
}

private void btnEx5Grp1E_Click(object sender, EventArgs e)
{
    ex5Q11IncorrectCount++;
}
#endregion
#region GroupBox2Events
private void btnEx5Grp2A_Click(object sender, EventArgs e)
{
```

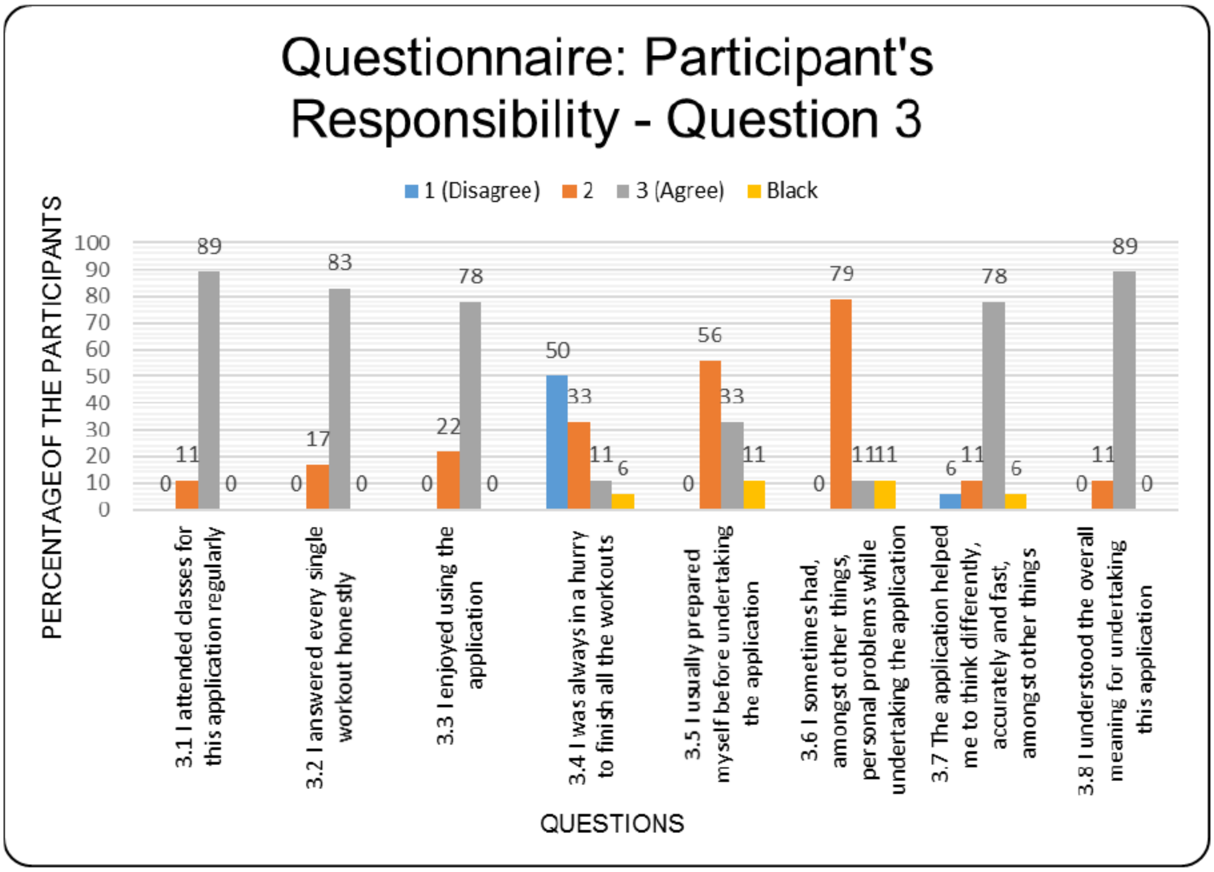
```
    ex5Q12IncorrectCount++;
}

private void btnEx5Grp2B_Click(object sender, EventArgs e)
{
    ex5Q12IncorrectCount++;
}

private void btnEx5Grp2C_Click(object sender, EventArgs e)
{
    ex5Q12IncorrectCount++;
}

private void btnEx5Grp2D_Click(object sender, EventArgs e)
{
     ex5Q12Correct = 1;
     MessageBox.Show("Your choice is Correct!", "CONGRATULATIONS!");
     grpEx5ARQ13.Visible = true;
     grpEx5ARQ12.Enabled = false;
}

private void btnEx5Grp2E_Click(object sender, EventArgs e)
{
     ex5Q12IncorrectCount++;
}
#endregion
#region GroupBox3Events
private void btnEx5Grp3A_Click(object sender, EventArgs e)
{
    ex5Q13Correct = 1;
    MessageBox.Show("Your choice is Correct!", "CONGRATULATIONS!");
    grpEx5ARQ14.Visible = true;
    btnClose.Enabled = true;
    grpEx5ARQ13.Enabled = false;
}

private void btnEx5Grp3B_Click(object sender, EventArgs e)
{
    ex5Q13IncorrectCount++;
}

private void btnEx5Grp3C_Click(object sender, EventArgs e)
{
    ex5Q13IncorrectCount++;
}

private void btnEx5Grp3D_Click(object sender, EventArgs e)
{
    ex5Q13IncorrectCount++;
}

private void btnEx5Grp3E_Click(object sender, EventArgs e)
{
    ex5Q13IncorrectCount++;
}
#endregion
#region GroupBox4Events
private void btnEx5Grp4A_Click(object sender, EventArgs e)
{
    ex5Q14IncorrectCount++;
}
```

```
private void btnEx5Grp4B_Click(object sender, EventArgs e)
{
    ex5Q14IncorrectCount++;
}

private void btnEx5Grp4C_Click(object sender, EventArgs e)
{
    ex5Q14IncorrectCount++;
}

private void btnEx5Grp4D_Click(object sender, EventArgs e)
{
    ex5Q14Correct = 1;
    MessageBox.Show("Your choice is Correct!", "CONGRATULATIONS!!");
    grpEx5ARQ14.Enabled = false;
    btnClose.Enabled = true;
}

private void btnEx5Grp4E_Click(object sender, EventArgs e)
{
    ex5Q14IncorrectCount++;
}
#endregion

private void tmrSecond_Tick(object sender, EventArgs e)
{
    if (second <= 59)
        second++;
    else
    {
        second = 0;
        minutes--;
        if (minutes > 0)
        {
           if (minutes == 1)
                lblMinutes.Text = Convert.ToString(minutes) + " minute remaining.";
            else
                lblMinutes.Text = Convert.ToString(minutes) + " minutes remaining.";
        }
        else
        {
           lblMinutes.Text = Convert.ToString(minutes) + " minute remaining.";
           tmrSecond.Stop();
           MessageBox.Show("Unfortunately Your Time Is Up.", "Sorry!");
           btnClose_Click(sender, e);
        }
    }
}
#endregion
```

Appendix D: Warm-up protocol



Appendix E: Gender distribution for the sample group members



Appendix F: Participant's responsibility