A MIXED METHODS INTERVENTION TO ENHANCE THE MATHEMATICS CAPABILITY OF FIRST-YEAR INFORMATION TECHNOLOGY STUDENTS AT A UNIVERSITY OF TECHNOLOGY

By

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DECLARATION

I, Jane Nelisa Freitas, declare that the contents of this thesis represent my own unaided work and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Signed: ______________________ Date: 5th February 2022

ABSTRACT

This study investigated the efficacy of a Mathematics Capability Intervention (MCI) module within Quantitative Techniques (QT) course, part of a Higher Certificate in Information and Communication Technology (HCINCT) programme.

Poor mathematical capabilities contributed to the problem of unsatisfactory throughput rates in IT programming courses. The level of High School mathematics compounded the situation. Analysis of student mathematics knowledge, highlighted that performance of many of the students was lower than that of 11 to 12-year-old pupils. An MCI module was designed and scheduled within Quantitative Techniques (QT) tutorial classes among one hundred and forty-seven first year ICT students.

The intervention was administered in 2015 to 147 information technology freshmen through class tutorials in the subject of Quantitative Techniques. Six research questions drove the investigation. The mixed methods sequential explanatory design approach was used to collect analyze and present the data. The main research question of the study was: What is the effect of the intervention programme on the mathematical knowledge of IT students upon entry into the HCINCT programme? To find answers to the main research question, hypotheses were constructed based on historical data.

A mixed methods sequential explanatory design (Creswell, 2013) underpinned the study. Quantitative instruments collected data derived from three formative pre-test assessments. Post-test assessments were conducted for two reasons:

- To ascertain whether students had acquired the desired skills; and
- To measure potential change in mathematics knowledge.

The qualitative aspect of the study comprised a purposively selected sample of eleven students agreed to participate in semi-structured interviews, contributing

qualitative data in response to open-ended questions. The null hypothesis (H_o) claimed that there was no statistically significant difference between the mean scores of the groups before and after the MCI (the treatment). The Solomon 1949 guidelines were used by the researcher to assign the students randomly into groups.

The analysis was performed using four groups: Experimental Group 1 (E1), Control Group 1 (C1), Experimental Group 2 (E2) and Control Group 2 (C2). Students' pre-test and post-test scores were evaluated to find answers to the main research question. The critical values used were t-test values gained from IBM SPSS (version 25) data outputs. Sub-question 1 enquired: Are the post-test scores of all groups significantly statistically different? The null hypothesis claimed that the means of each group were the same. To support the null hypothesis of sub-question 1, the students' post-test scores were evaluated by performing a one-way (between groups) ANOVA.

Sub-question 2 enquired: What evidence do we have to suggest that the sample came from a population for which the mean score was 50? The null hypothesis claimed that there was no statistically significant difference between the mean score of the students at the University of Technology where the study was conducted and the mean score of the HCINCT 2015 students. To test the null hypothesis, the final-year assessment scores of the HCINCT students were used. Sub-question 3 enquired: Is there a statistically significant difference between the HCINCT 2016 mean score and the HCINCT 2015 mean score on exit? To support the null hypothesis, the final-year assessments of the HCINCT students were evaluated.

Sub-question 4 enquired: Under which circumstances did the students' results improve? The null hypothesis claimed that there were no improvements in the students' results. Teaching methods and the students' interview responses were evaluated for answers. It emerged that teaching methods provided the best answer.

The descriptive statistics results showed that there was a noticeable difference between the mean values for E1 scores. The mean ($\bar{X}$) for the C1 pre-test ($\bar{X}$ = 39.62, SD = 6.3) was not noticeably different from the C1 post-test ($\bar{X}$ = 39.16, SD = 5.0). The researcher further assessed the differences between these two sample means using a paired samples t-test to assess statistically significant differences between the scores on the pre-test and the post-test measures for groups E1 and C1.

A further analysis was performed to determine whether or not the means of the 4 post-test groups were significantly different from one another. A one-way between groups ANOVA was performed. There was a significant effect between the mathematical knowledge scores of the 4 post-test scores (E1, C1, E2 and C2. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the E1 group was significantly different than the C1 group. However, the E1 group did not significantly differ from the E2 group. The two control groups, C1 and C2 did not differ from one another. Since there was a question of normality for the C1- Pre Test group as determined by the Shapiro ($p < .05$), a Kruskal-Wallis test was conducted comparing the results of the Post-Test for all 4 groups: E1, E2, C1, C2.

Statistical analysis of quantitative outcomes indicates post-test scores of the IT students in an experimental group who experienced the intervention treatment demonstrated enhanced mathematical knowledge. No such improvement was noted in a control group, not exposed to the MCI treatment. There is thus a probability that students' mathematical capabilities improved, but not by chance. Quantitative findings are supported by qualitative data.

In summary, the Mathematics Capability Intervention (MCI) module has the potential to influence mathematical knowledge of IT students in several ways by:

- Confirming that students require a level of mathematical knowledge upon which to scaffold their quantitative skills;

- Demonstrating that students should be encouraged to assume responsibility for acquiring mathematics knowledge themselves;
- Supporting the synthesis of critical evaluation skills regarding quantitative techniques associated with in-class tutorial content; and
- Highlighting the power of students' desire to acquire mathematics capability.

The efficacy of innovative mathematics interventions implemented among students within different universities is worthy of additional exploration. Further development of the MCI module could offer the UoT widespread and substantive benefits within different departments. The module could hereby cater for all mathematically at-risk students. Moreover, theoretical outcomes of the module design could inform adjustments to outdated syllabi, allowing for the inclusion of new and contextualised learning materials. QT class tutorials could focus more on allowing students to use quantitative techniques to solve real-world problems. Thus, students could be afforded constructivist opportunities to solve mathematical challenges in their own ways.

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Opinions expressed in this thesis and the conclusions arrived at are those of the author and are not necessarily to be attributed to the Department of Higher Education.

DEDICATION

This research is dedicated to my son, Dumile Sukati and my nephew, Lazola Lisa. Thank you for spending long weekdays and weekends with me in my office, encouraging me to pursue my doctoral endeavours with your smiles and positive attitudes.

To Anders Käll, Herta Dahl and Nomaxabiso Nduna: Thank you for believing in me and for always supporting me in all my endeavours.

To my mother, Nompi Kamasse: Thank you for pushing me hard.

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TERMINOLOGY

ACRONYM	CLARIFICATION OF ABBREVIATIONS
ADDIE	Analysis, Design, Development, Implementation and Evaluation
APS	Addition Point Score
C1	Control Group 1
C2	Control Group 2
CPUT	Cape Peninsula University of Technology
DHET	Department of Higher Education and Training
DOHE	Department of Higher Education
E1	Experimental Group 1
E2	Experimental Group 2
ECDOD	Eastern Cape Department of Education
ELT	Experimental Learning Theory
FET	Further Education and Training
FID	Faculty of Informatics and Design
GDP	Gross Domestic Product
HCINCT	Higher Certificate in Information and Communication Technology
HELTASA	Higher Education Teaching Association of Southern Africa
IBSE	Inquiry-Based Science Education
ICT	Information and Communication Technology
IBM	International Business Machines Inc
ISPSS	Statistical Package for the Social Sciences
IT	Information Technology
MCI	Mathematics Capability Intervention
MLNN	Multi-Layer Neural Network
MYP	Middle Years Programme
NN	Neural Network
NQF	National Qualifications Framework
OECD	Organisation for Economic Co-operation
PISA	Programme for International Student Assessment
QT	Quantitative Techniques
QUAL	Qualitative
QUANT	Quantitative
SA	South African
SAQA	South African Qualifications Authority
STEM	Science, Technology and Mathematics
SWE	Swedish
TALIS	Teaching and Learning International Survey
TIMSS	Trends in International Mathematics and Science Study
TVET	Technical and Vocational Education and Training
UoT	University of Technology
ZPD	Zone of Proximal Development

1 CHAPTER 1: INTRODUCTION

French mathematician Henri Poincaré (1854–1912) suggested: “Mathematical discoveries, small or great are never born of spontaneous generation. They always presuppose a soil seeded with preliminary knowledge and well prepared by labour, both conscious and subconscious” (Platonic Realms, 2019).

Literature demonstrates that many students in transit from high school education to university education are mathematically underprepared to undertake university courses that require participants to have a solid foundational arithmetic background upon which to scaffold university education (Brandell, Hemmi and Thunberg, 2008; Alexander, 2013; Rohlwink, 2015). The challenge rests in the students’ early learning in which memory networks for arithmetic were underdeveloped (Salilas and Wicha, 2012). Some authors argue that perhaps the South African high school Mathematics education is built to miss the fundamental aspects that are needed to empower its recipients (Howie and Plomp, 2002; Chisholm, 2005). Some authors suggest that there is a misalignment between the nature of the entrant’s pre-tertiary mathematical experience and the level of mathematics at First-year University (Hourigan and O’Donoghue, 2007; Clark and Lovric, 2008; Neugebauer and Schindler, 2012; Psycharis, 2016).

Many authors state that the solution to solving the scourge of the under preparedness in mathematics of first-year students can be accredited to several aspects. There are authors who claim that poor student mathematics performance is the cause of the gap in the students’ high school mathematical skills and tertiary mathematics (Kezar, 2013). Other authors argue that students need to have collaborative mathematical capabilities to acquire the mathematical skills that will assist them in their transition to higher education mathematical studies (Cirino, Tolar, Fuchs and Huston-Warren, 2016).

In contrast, some writers infer that ability in mathematics enables success in acquiring the mathematical skills that foreground the required skills for tertiary education (Wang, Guo and Jou, 2015; Ramirez, Chang, Maloney, Levine and Beilock, 2016; Ludvigen, Nortvedt, Pettersen, Pettersson, Sollerman, Olafsson, Taajamo and Caspersen, 2016). Another set of authors attribute the mathematics gap to the student's self-efficacy towards learning mathematics (Bandura, 2006; Azevedo, 2014; Ben-Eliyahu and Bemacki, 2015).

Some authors take the scourge of mathematics education for high school students in transit to tertiary education as a matter of student attitude. This group of authors suggests that a positive attitude towards the ability to be successful in a tertiary course such as IT programming is necessary in students (Gedrovics and Cēdere, 2014; Kwan and Wong, 2015; Cēdere *et al*., 2015; Bonne and Johnston, 2016; Savelsbergh, Prins, Rietbergen, Fechner, Vaessen, Draijer and Bakker, 2016).

Whitehead (1911) begins his book titled *An Introduction to Mathematics* with a discussion on the trivial encounters that most people have with mathematics. In line with Whitehead's lamentations, this thesis describes the research that was undertaken to determine the effect of the MCI administered to information technology (IT) students in the Higher Certificate in Information and Communication Technology (HCINCT) programme in 2015. The mandate to conduct this study was obtained by the researcher from the project sponsor in January 2015. From February 2015 to October 2015, 147 IT freshmen participated in voluntary class tutorials. These class tutorials were administered to the research participants in the subject of Quantitative Techniques (QT). Quantitative Techniques is one of the three major courses in the HCINCT one-year programme run by the IT Department at the University of Technology (UoT) where this research was conducted. Class tutorials in QT are conducted to augment students' mathematical skills.

The students' mathematical skills were revealed as needing enhancement by the marks they attained in their Matric Mathematics results. These marks were confirmed to be weak according to an admissions proficiency scale used by the IT

Department for acceptance of students. The results of the voluntary pre-tests that were administered to some of the research participants (Experiment Group 1 (E1) and Control Group (C1)) before they assumed their studies in the HCINCT programme also confirmed that the students' mathematical skills were below the level of proficiency needed to embark on their chosen studies.

Alexander (2013) explained that the objectives of the HCINCT programme are (a) to augment the mathematical capabilities of first-year IT students; (b) to increase the throughput rates of the three-year National Diploma in IT; and (c) to equip course participants with IT skills that enable students who wish to seek employment opportunities in the IT fraternity upon course completion. Hence, further research was necessary to measure the students' mathematical capabilities in order to establish the level at which the mathematics intervention programme could be implemented and upon which IT programming skills could be scaffolded.

This research is thus relevant and follows upon research by various authors (Brandell, Hemmi and Thunberg, 2008). The abovementioned authors argue that students who enter university studies that require a certain level of mathematical skills upon which to scaffold their studies are mathematically underprepared. This notion concurs with Hourigan and O'Donoghue (2007) who conducted studies on the effect of high school Mathematics on the transition of underprepared high school students to tertiary education. The above authors claim that the students' underpreparedness for university studies has created a gap between the mathematical capability that they have on entry into their tertiary studies and the mathematical skills that are expected by universities.

This research qpplies the mixed methods sequential explanatory design approach (Creswell, 2013) to find answers to the research questions and all the data used were generated in action (Chahine, 2013 ; Mason, 2016). The students both learnt and participated in the research; they gave suggestions and processes were fixed on an ongoing basis. The mixed methods sequential explanatory design approach was chosen for this study because of its methodological eclecticism that provides multiple insights in research (Worthley, 2007; Tashakkori and Teddlie, 2010).

This investigation added the following dimensions to the work: (a) the study analysed the mathematical capability of IT freshmen prior to the QT class tutorials through a mathematics intervention in the HCINCT programme; (b) the study used statistics to predict where many of the IT freshmen of 2015 may have missed or lost the required foundational arithmetic skills upon which to scaffold IT programming skills; (c) the study offered the students opportunities to reflect on their role in their learning; and (d) the study offered the students opportunities to design their own mathematics curriculum with the safety net of a lecturer to support them.

Although this study highlighted the efficacy of the Mathematics Capability Intervnetion (MCI) in the HCINCT programme through the subject of QT, the study did not investigate the causes of the gaps in the students' mathematical capabilities since this topic was not within the scope of the study. The theoretical framework of Kolb (2015) was used as a lens for this investigation to report on the practices of first-year IT university students in accessing enhancement of their mathematical capabilities at a UoT in South Africa. The findings suggested that 18-year-old university students entering their university studies are equipped with foundational arithmetic skills and practical mathematical skills that are weaker than those of 11- to 12-year-old pupils in primary schools in the South African education system. The Eastern Cape Department of Education (ECDOD), (2016) provided an insight into the type of mathematics taught to 11- to 12-year-old primary school pupils in South Africa.

The analysis of the pre-test scores demonstrated a ratio of 1:20 of mathematically prepared university students who take courses that require them to be equipped with a good numerical background upon which to scaffold IT studies. Scaffolding mathematics education enhances the students' mathematical capabilities, which is paramont for acquiring digital literacy (Anghileri, 2006; Francke and Alexander, 2010; Hoda and Andreae, 2014; Ting, 2015; Brower, Woods, Jones *et al.*, 2017).

The findings of this study revealed that the students were familiar with matriculation examinations through practising on past examination papers for a long time.

However, when the same questions were asked in a different setting, the students answered them incorrecIty. This outcome showed that passing Matric Mathematics examinations does not necesssarily mean that the students have the required quantititave skills on entry into the (HCINCT) programme. It was concluded that the students did not have adequate foundational arithmetic skills to scaffold IT education.

1.1 PROBLEM STATEMENT

First-year IT students enrolled in the HCINCT programme at the UoT where this study was conducted are expected to have passed either Mathematics or Mathematics Literacy in their final matric examinations. However, the mathematics performance of many first-year IT freshmen enrolled in the HCINCT programme in 2015 was lower than the mathematical capabilities of current 11- to 12-year-old pupils attending Grade 6 in a South African primary school. This claim was based on the researcher's analysis of the students' pre-test and post-test scores. The assessments were administered to the students during the enhancement of their mathematical capability through QT class tutorials. An intervention to augment the mathematical capabilities of IT students collaborated efforts, which included scaffolding practices that enhanced mathematics learning and promoted working with Technical and Vocational Education and Training (TVET) colleges (Anghileri, 2006; Vogel, Reichersdorfer, Kollar, Ufer, Reiss. and Fischer, 2013; Alexander, 2013).

1.1.1 Research problem

The problem regarding throughput rates in IT programming courses rests in the mathematical skills of first-year IT students upon entry (Alexander, 2013). This is compounded by the level of mathematics education that students are taught at high school (Chisholm, 2005). Since high school mathematics education in South Africa is set at a lower standard compared with high school education in the same grades in other countries (Värgrynen, 2003; Fleisch, 2008). The research problem lies in extracting design guidelines for an intervention to enhance the mathematical capabilities of IT students upon which the desired IT programming skills can be scaffolded.

The design guidelines were integrated to include a focus on instructional and regulatory discourse (Norton, 2008). Instructional and mathematics curriculum guidelines for adult education (Valenzuela, 2018) were followed to focus the mathematics intervention programme on the desired mathematical needs of the students in order to maximise time and human resources. This was due to the fact that the mathematics intervention programme was administered through the QT course, which has its own academic scope, time lines and expected deliverables. The QT tutorials were designed to provide students with practical experiences through interactive engagements using the World Wide Web so that their mathematical thinking skills would be challenged and developed in order for them to acquire the desired numerical skills (Chen, 2010).

1.1.2 Practical problem

The practical problem is that 18- to 19-year-old students who possess less foundational arithmetic skills than 11- to 12-year-old learners at primary school in South Africa are entering university studies that demand a strong foundational arithmetic background. Trends in International Mathematics and Science Study (TIMSS) tests were introduced for the first time in South Africa in grades 3, 6 and 9 in 1999. The results from Grade 9 students' participation in the TIMSS assessment for that year showed that South African learners perform poorly when compared with same age and same grade pupils in other countries. The international average for the test was a score of 500; South African test-takers achieved an average of 275.

The South African score was regarded as the lowest score for a test-takers. Students from Singapore obtained the highest scores in the 1999 TIMSS assessment test. Despite these concerns, under preparedness in mathematics in first-year university students is not a problem that is exclusive to South Africa. Universities worldwide have seen a decline in student graduation numbers of mathematics-related degrees. According to Sahlberg (2006), a country that invests financial and legal resources in providing teachers with financial and policy backing from government to create interventions realises better student results.

Mathematical knowledge in South Africa is low due to a learning gap at primary school level and insufficient mathematics knowledge for mathematics teachers (Mogari, 2014). While Klofsten (2000), Hsu, Roberts and Eesley (2007), Rasmussen and Borch (2010) and Tshikovhi and Shambare (2012) posit that transitional entrepreneurship and its positive impact on the global economy are accredited to UoT's training students in problem-solving skills. However, there is a gap in the current understanding. The problems that are experienced in the transition from high-school mathematics education to university education are also due to the rapid change in IT innovation, product development and the market demands for innovative and quick development turnaround of IT products (Freitas, 2013).

Therefore, the mathematics education that is given to students needs to develop students' spatial visualisation ability so that they can be trained to think broadly and create innovative solutions to problems in everyday life (McGee, 1979) describes spatial visualisation ability as a subset of spatial ability, which is a factor of the human intelligence structure. The current gap in understanding and the actual IT need for mathematics education in high school graduates has created a research problem that this study tried to address.

1.2 AIM OF THE RESEARCH

The aim of this research was to explore the mathematical capabilities of IT students upon entry into the HCINCT programme and subsequently, to develop a business model for the efficacy of the enhancement of these mathematical capabilities based on the students' post-test scores upon exit from the HCINCT foundation programme.

1.2.1 Research questions and objectives

The research objectives were formulated using the study's research questions. The objectives were constructed to guide, drive, align and synchronise all the components of the research process towards gaining answers to the research questions and to solving the research problem, as illustrated in Table 1.1.

1.2.2 Rationale

The rationale that forms the pragmatic dimension of this introduction is to suggest that the mathematics problem does not lie in the transition from high school to university. The problem is that there are 18- to 19-year-old students who enter university studies with mathematical capabilities below those of 11- to 12-year-old pupils. Hence, the failure rates are high across all programming courses. Many of the students that enter IT programming courses have a huge mathematics gap that requires them to return to their last years of primary school mathematics in order to become competent in the IT programme. A one-year mathematics intervention is not enough to remedy the situation.

Despite the fact that the QT course of 2015 had a 79% pass rate and a 12% drop-out rate, it showed a 33% increase in the student pass rate for QT compared with the 46% pass rate attained by students who took the QT course in 2014. Students are expected to acquire a 65% aggregate pass across all 11 subjects in the HCINCT programme to be eligible for the National IT Diploma course at the UoT. However, the success of the intervention is measured on the overall student pass rate in the entire HCINCT programme. At the end of the HCINCT programme, there was only an overall 48% pass rate.

1.2.3 Previous research

Literature demonstrates that many students in transit from high school education to university education are mathematically underprepared to undertake university courses that require participants to have a solid foundational arithmetic background upon which to scaffold university education (Brandell, Thunberg and Hemmi, 2008; Alexander, 2013; Rohlwink, 2015). The challenge rests in the students' early learning in which memory networks for arithmetic were underdeveloped (Salilas and Wicha, 2012). Some authors argue that perhaps the South African high school Mathematics education is built to miss the fundamental aspects that are needed to empower its recipients (Howie and Plomp, 2002; Chisholm, 2005). Some authors suggest that there is a misalignment between the nature of the entrant's pre-tertiary mathematical experience and the level of mathematics at First-year University (Hourigan and O'Donoghue, 2007; Clark and Lovric, 2008; Neugebauer and Schindler, 2012; Psycharis, 2016).

Many authors state that the solution to solving the scourge of the under preparedness in mathematics of first-year students can be accredited to several aspects. There are authors who claim that poor student mathematics performance is the cause of the gap in the students' high school mathematical skills and tertiary mathematics (Kezar, 2013). Other authors argue that students need to have collaborative mathematical capabilities to acquire the mathematical skills that will assist them in their transition to higher education mathematical studies (Cēdere, Jurgena, Helmane, Tiltina-Kapel and Praulite, 2015; Cirino *et al.*, 2016).

In contrast, some writers infer that ability in mathematics enables success in acquiring the mathematical skills that foreground the required skills for tertiary education (Wang, Guo and Jou, 2015; Ramirez *et al.*, 2016; Ludvigen *et al.*, 2016). Another set of authors attribute the mathematics gap to the student's self-efficacy towards learning mathematics (Bandura, 2006; Azevedo, 2014; Ben-Eliyahu and Bemacki, 2015).

Some authors take the scourge of mathematics education for high school students in transit to tertiary education as a matter of student attitude. This group of authors suggests that a positive attitude towards the ability to be successful in a tertiary course such as IT programming is necessary in students (Gedrovics and Cēdere, 2014).

1.3 RESEARCH STRATEGY

At first, the Mathematics problem outlined earlier led to the design of course content followed by the design of an intervention culminating in the design of assessments.

To address the aims of the study and in order to answer the research questions, the strategy outlined in this section was implemented,

This study used a mixed methods approach to address the research questions and thus find a solution to the research problem on which the study is based. In this investigation, three quantitative tools and three qualitative tools were used to collect data. The qualitative tools were used to validate whether the results that were derived using quantitative tools were similar to the results from the data that were collected using qualitative tools (Denzin, 2017). The students were first evaluated to determine their eligibility for the HCINCT programme using the admission point score (APS). (Barlow and Hayes, 1979)

Thereafter, the students were randomly assigned to groups (Solomon, 1949; Friedlander and Robins, 1995; Goodwin and Goodwin, 2016). These were students allocated to the experiment groups (E1) and the control group (C2). A pre-test assessment at the level of 11- to 12-year-old learners in Grade 6 was administered to the two groups of students. The students' mathematical capabilities were evaluated before the students started the QT class tutorial that was designed to augment the students' mathematical capabilities. An in-depth discussion of the pre-test and the post-test assessments is presented under the methods section in Chapter 3 of this thesis document.

Finally, interviews conducted among IT experts explored views of numeracy skills of IT students who were migrating from high school and who were enrolling in university studies. Appendix H sets out the questions in the interview protocol.

1.3.1 Research paradigm

The researcher used anti-positivism to explore alternatives in the subjective world in order to understand what the students say about their mathematical skills (Cronje, 2011). This was coupled with a functionalist positivist paradigm, which was used to drive this study because the researcher was interested in developing solutions objectively by suggesting that the situation could be improved by tightening up on the rules. Regulations promote social change in information and communication technology (ICT) education, economic development and the education of mathematics teachers (Sahlberg, 2006; Calitz, 2010). In addition, the researcher was inquisitive to learn what would be the results obtained through mixed methods.

1.3.2 Designing the formative assessments for the intervention

The history of mathematics education in South Africa was researched and old examination papers used in South Africa before and after the implementation of Curriculum 2005 were assessed for suitability in the mathematics intervention under study (Department of Education, 1995). The matriculation curricula for Mathematical Literacy and Mathematics, the latter often being referred to as pure Mathematics in South Africa, were checked and studied to understand the content of high school Mathematics in the country (Aird, du Toit, Harrison, van Duyn and van Duyn, 2013).

South African textbooks for both Mathematical Literacy and pure Mathematics were checked against the Swedish and the British mathematics textbooks at the same high school grade levels. Mathematicians working in the Faculty of Engineering and in the Faculty of Informatics and Design at the UoT where this study was conducted were consulted and their works were read. Journal articles discussing a need for skilled IT personnel because there is a shortage were consulted. Articles in academic journals and theses on the transition from secondary education to tertiary education were located.

Course materials for the enhancement of the mathematics capabilities intervention were developed based on the senior management guidelines of the IT Department. Learning plans were linked to the South African National Qualifications Framework (NQF) level 5 (Department of Education, 1995; South African Qualifications Authority (SAQA, 2011). Assessments were developed after checking and comparing the prescribed books for matriculation (Schoenfeld, 2007; Sriraman and

Lee, 2012; Schoenfeld, 2013). Past examination papers for Mathematical Literacy and pure Mathematics were accessed (Western Cape Department of Education, 2010)), while the work of Bloom, Englehart, Furst, Hill and Krathwohl (1956), Seaman, (2011) and Hwang, Chen and Huay, (2016) was used to guide the process for setting and assessing student assessments.

Mathematical theory were used as building blocks to form the crux of the problem-based learning approach used in this investigation (Piaget and Inhelder, 1969; Qayumi, 2001; Maton and Moore, 2010; Case, 2014; Barrouillet, 2015). The time allocation for matriculation revision was three weeks. The pace of the revision work was set at a fast tempo, which was based on the assumption that the research participants entered their first-year university studies mathematically prepared. The prescribed South African Grade 10 Mathematics book was compared with mathematics books used in the Middle Years Programme (MYP) of the International Baccalaureate Curriculum and the Swedish Mathematics book levels A to E of.

The researcher compiled the assessment after checking for consistency and referring to guidelines for setting up mathematics assessments (Buhagiar and Murphy, 2008; Poggio, Glasnapp and Yang, 2005; Schoenfeld, 2007).

1.3.3 Administration of learning activities

The pre-tests were not for marks; the students marked their own tutorials. The lecturer of the project managed the marking process of pre-test 1 and pre-test 2, while pre-test 3 was peer marked by the students. Peer-marking allowed for introspection and retrospection and encouraged further discussions among students in groups regarding each other's test results and strategies thereof. The lecturer and the students went through the problems, discussing and solving each problem. Students had the opportunity to address one or two problems repeatedly before trying a slightly different problem. Some students chose to use chalk and board to solve the problems while asking questions. The lecturer marked the post-test one year later.

1.3.4 Research design

The research design for the pre-test and post-test control groups under the quasi-experimentation category was found to be suitable for data collection of the students' assessment scores (Thomas and Nelson, 2001). Solomon's four group study design was used to randomly assign students for experimentation in the study (Solomon, 1949). The pre-test scores were used to measure how the HCINCT programme should be structured. The post-test scores were used to evaluate the effect of the enhancement of students' mathematical capabilities upon exit of the HCINCT programme. Meltzer (2002) used students' pre-test scores to substantiate his claim that mathematical skills are associated with variations in students' abilities to acquire conceptual learning gains in physics. The same principle used by Meltzer (2002) was followed in this study.

Since the levels of mathematical skills of the students comprising the population of this study were unknown upon entry, a voluntary grade 6 pre-test was administered to 74 of the 147 students to fill this gap in information. The other 73 students did not take the pre-test because the researcher used them as a control group. The two groups of students through which the grade 6 pre-test was not administered to were students randomly assigned to Experimental Group 2 (E2) and the Control Group 2 (C2) by the researcher.

1.3.5 Research instruments

Overall, this study used a medley of research tools for data collection because the research questions, the problem statement, the research problem and the aims and objectives directed this study towards a mixed methods approach (Morse, 2003; Creswell, 2013). The data obtained using qualitative instruments were used to check for consistency and reliability of the data obtained using quantitative instruments (Merriam, 2009; Creswell, 2013; Mason, 2016). Tables 1.2, 1.3 and 1.4 illustrate the research instruments used.

1.3.6 Research questions, hypotheses, objectives and instruments

The review of previous research presented in Section 1.7 supports the research questions posed in this section. The study comprises one main and five sub-questions. The main and sub-questions one to three are designated as quantitative research questions whereas sub-questions four and five are listed as mixed methods questions. Null and alternative hypotheses map to the research questions which in turn relate to one main and five research objectives. The research objectives were formulated using the study's research questions. They serve to guide, drive and synchronise all the components of the research process. They align with the research questions which consequently address the research problem. Finally, Table 1.1 aligns the research instruments introduced in Section 1.7.2 link to research questions, hypotheses and objectives of the study.

Table 1.1: Pairing research questions with instruments used

Research questions	Instrument used for data analysis
Main research question (quantitative)	Pre-test and post-test assessment scores
Sub-question 1(quantitative)	Post-test assessment scores
Sub-question 2 (quantitative)	HCINCT 2015final-year students assessment scores
Sub-question 3 (quantitative)	HCINCT 2015 and HCINCT 2016 students' assessment scores
Sub-question 4 (mixed methods)	Interview responses of students in a South African UoT and teaching strategies

The methods of data analysis and data presentation that were sourced through the research instruments demonstrated in Tables 1.2, 1.3 and 1.4 that follow. They set out research questions, hypotheses, objectives and data analysis instruments.

Table 1.2: Quantitative Research Questions, Hypotheses, Objectives and Data Analysis Instruments Main and Sub-Questions1 and 2

Quantitative Research Questions	**Hypotheses**	**Objectives**	**Data Analysis Instruments**
Main Research Question *What is the effect of the intervention programme on the IT students upon entry into the HCINCT programme?*	**Main Null Hypothesis (Ho)** There is no statistically significant difference between the groups' mean scores before and after the MCI. **Main Alternative Hypothesis (H_a)** There is a statistically significant difference between the groups' mean scores before and after the MCI	**Main Objective** To establish if the intervention was successful in enhancing the students' mathematics capabilities through the QT class tutorials in 2015	Pre-test and post-test assessment scores
Sub-Question 1 *Are the post-test scores of all groups statistically different?*	**Sub-Question 1 Null Hypothesis (Ho)** The means of each group are the same. **Sub Question 1 Alternative Hypothesis (Ha)** There is a mean difference between at least two groups.	**Objective 1 Sub-Question 1** To establish whether or not the mean post-test scores of the four groups were significantly different	Post-test assessment scores
Sub-Question 2 *What evidence do we have to suggest that the sample came from a population such that the mean score was 50?*	**Sub-question 2 Null Hypothesis (Ho)** There is no statistically significant difference between the mean score of the UoT students and the mean score of the HCINCT students. **Sub-Question 2 Alternative Hypothesis (Ha)** There is a statistically significant difference between the mean score of the UoT students and the mean score of the HCINCT students.	**Objective 2 Sub-Question 2** To establish if the sample mean score in HCINCT is a true parameter that represents the IT students' population mean score in 2015	HCINCT 2015 final-year students assessment scores

Table 1.3: Quantitative Research Questions, Hypotheses, Objectives and Data Analysis Instruments Sub-Question 3

Quantitative Research Questions	**Hypotheses**	**Objectives**	**Data Analysis Instruments**
Sub-Question 3 *Is there a statistically significant difference between the HCINCT 2016 mean score on exit and the HCINCT 2015 mean score on exit?*	**Sub-Question 3 Null Hypothesis (Ho)** There was no statistically significant difference between the mean score of the HCINCT 2016 students and the mean score of the HCINCT 2015 students on exit. **Sub-Question 3 Alternative Hypothesis (Ha)** There was a statistically significant difference between the mean score of the HCINCT 2016 students and the mean score of the HCINCT 2015 students on exit.	**Objective 3 Sub-Question 3** To evaluate if the intervention made a statistically significant difference in enhancing the students' mathematical capabilities	HCINCT 2015 and HCINCT 2016 students' assessment scores

Table 1.4: Mixed Methods Research Questions, Hypotheses, Objectives and Data Analysis Instruments Sub-Question 4

Mixed Methods Research Questions	**Hypotheses**	**Objectives**	**Data Analysis Instruments**
Sub-Question 4 *Under which circumstances did the students results improve?*	**Sub-Question 4 Null Hypothesis (Ho)** There were no circumstances that indicated improvements had been achieved in the students' results. **Sub-Question 4 Alternative Hypothesis (Ha)** There were circumstances that indicated improvements had been achieved in the students' results.	**Objective 4 Sub-Question 4** To establish the criteria for successfully addressing improvement to the students' mathematics results	Interview responses of students in a South African UoT and teaching strategies together with the feedback from experts from the IT domain.

The methods of data analysis and data presentation that were sourced through the research instruments demonstrated in Tables 1.2, 1.3 and 1.4 are discussed in the following section 1.3.7.

1.3.7 Data analyses and interpretation

Data that were gathered from the student's assessment scores were manually captured into Microsoft Excel and thereafter uploaded into *IBM SPSS s*tatistics (version 25.0) for data analysis. Eight constructs that emerged from two literature reviews that were conducted (see Table 3.2 in Chapter 3) were used to construct qualitative interview questions. The students' responses gathered through one-on-one semi-structured interviews were coded into categories (Merriam, 2009). Two main categories affective and scaffolding emerged from the eight constructs obtained through the literature reviewing process.

The categories were used to classify the students' responses for interpretation and data presentation. The Responses from two senior academic personnel from the Swedish UoT and the Latvian UoT clustered the categories affective and scaffolding. The data analysis, data interpretation and data presentation followed a mixed methods sequential explanatory design approach (Creswell, 2013). The research questions that were constructed using the emerged constructs were used to present the qualitative data findings in chapter 4 of this thesis document.

1.3.8 Students' academic engagements

Apart from the formative assessments mentioned previously, students had two major assessments per term. First term test 1 contributed 40% towards the joint 100% of the students' end-of-term mark in the QT course and Test 2 (end-of-term examination) contributed 60%. The style of the assessment, whether to use a formative or a summative assessment, was decided upon by the researcher with the approval of line management. The makeup of the percentage variations is laid down in the university's black book of rules. The IT students in the HCINCT foundation programme wrote one summative assessment called Test 1 in the middle of March 2015 and Test 2 was taken at the beginning of April that year.

Test 2 was the end-of-term examination for Term 1. The students' test and examination for the first term comprised high school revision work and the QT work of the first term, which was made up of Mathematics at NQF level 5. The first three chapters of the QT course were examined. Chapter One encompassed binary and other numbering systems, Chapter Two was an introduction to algebra and Chapter Three was logic and logic functions. Figure 1.1 demonstrates the percentage pass rates in the first summative assessment that was styled Test 1 (a class test) and was taken by the students after spending approximately two months in the HCINCT course.

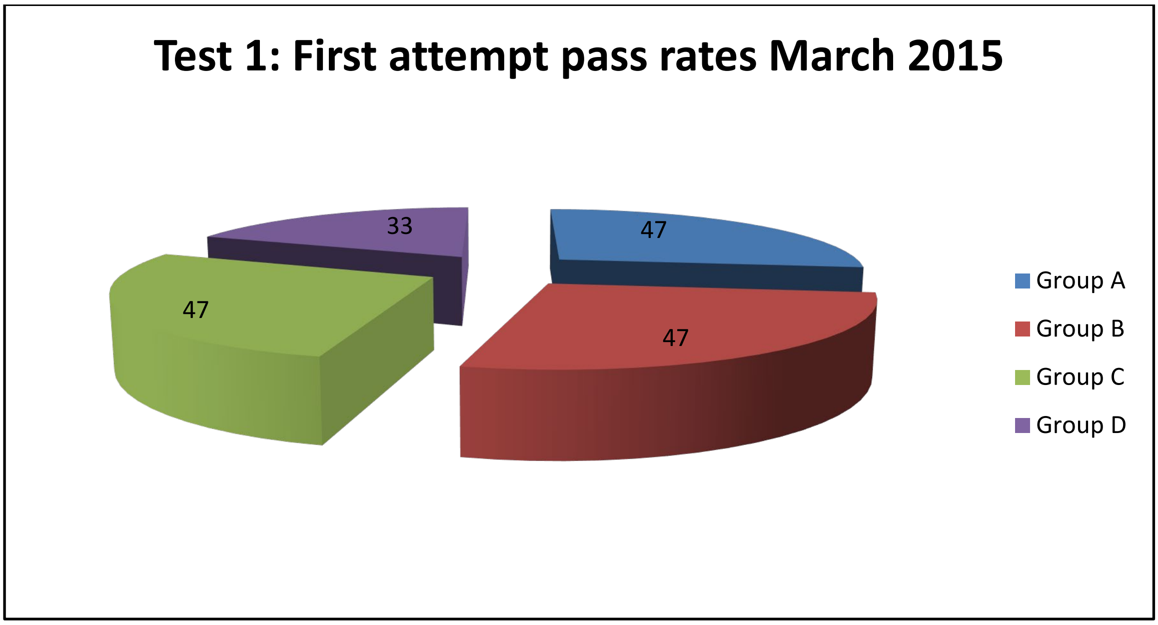


Figure 1.1: Term 1 Test 1 QT passes rates

Figure 1.1 shows 44% of the mean of all means for students who passed in all four groups. Since 50% is the minimum expected class average pass, the students performed below the class average. A 60% and above class average is a better measure of student class performance. Figure 1.2 illustrates the failure rates of HCINCT students for Test 1 of the first term, a part of the first academic year.

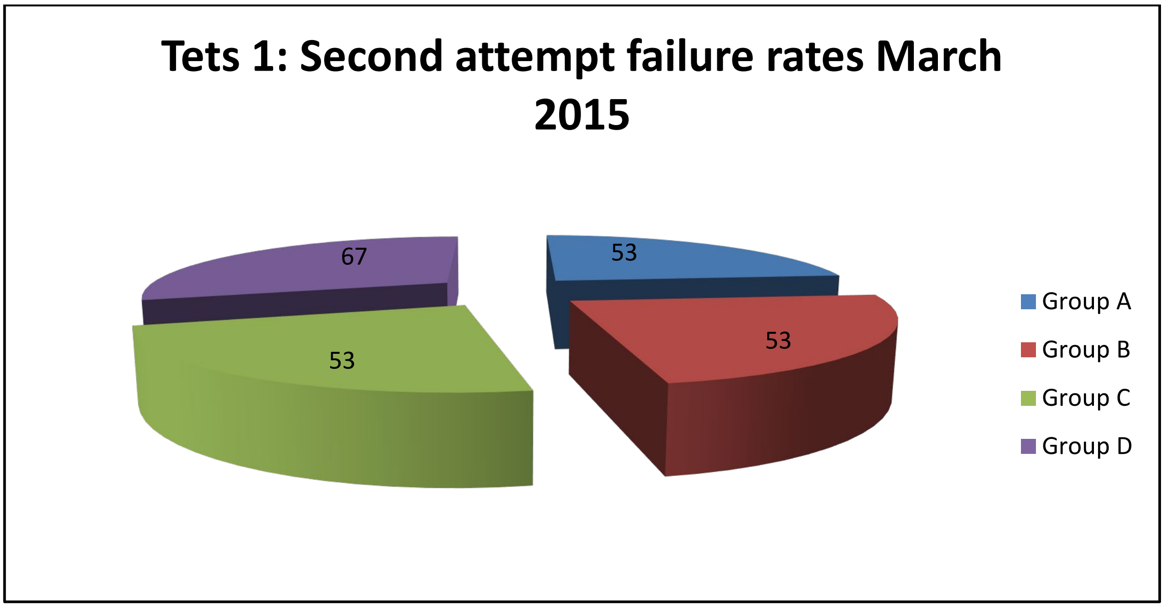


Figure 1.2: Term 1 Test 1 QT failure rates

A significantly different trend existed among the groups' performances in the first two terms. Towards the second term, the students in Group D out-performed the students in groups A, B and C. The cause for this trend was discovered at the end of this study. Students who had entered the QT class tutorials in the HCINCT programme as mathematically underprepared had, during the year, recognised their strengths in working as a group and had utilised the skills of the high-performing students.

This supports the literature review that states that students' positive self-belief and confidence together with collaboration increases the transfer and transmission of mathematical skills and transforms students (Sangcap, 2010; Mohamed and Waheed, 2011). Test 2 was a formal examination. The test was a pen and paper structure (Bergstrom, 1992; Poggio, Pogio, Glasnapp and Yang et, 2005; Papadopoulos and Dagdilelis, 2008).

The use of calculators and formula sheets was prohibited during the test. Figure 1.3 displays the students' marks for Term 2 of the first academic year, 2015.

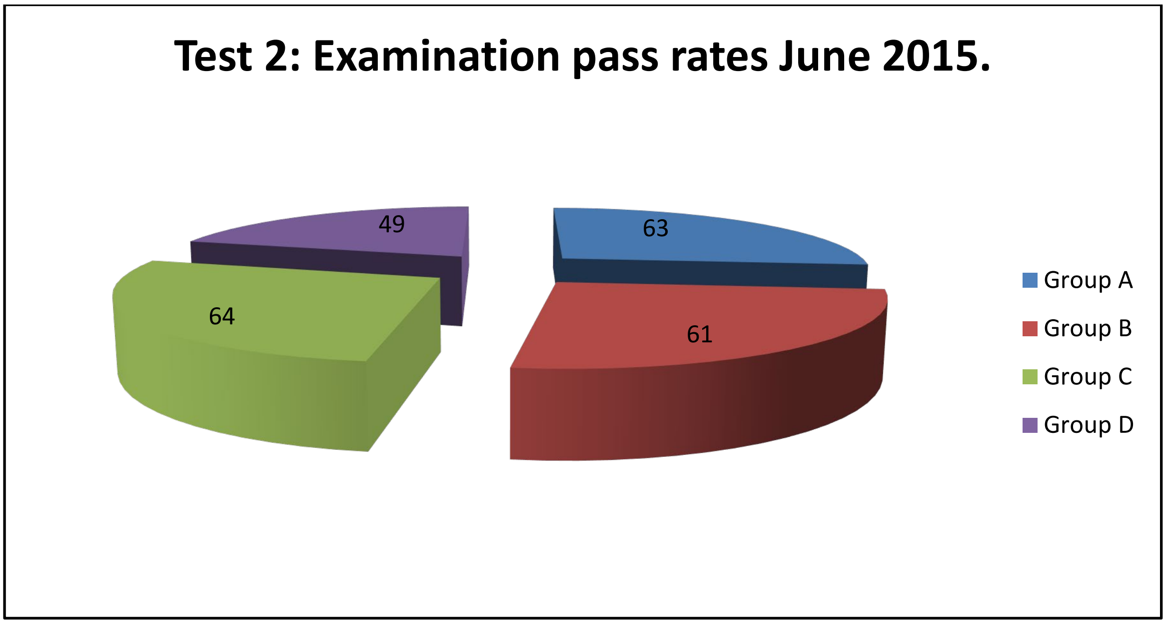


Figure 1.3: Term 2 Test 2 QT passes rates

In Figure 1.3, the overall mean of all means for Test 2 was 48 %. There was a percentage increase of 4 % in Test 2 in the June examinations.

Figure 1.4 represents the percentage failures for the June examination, which is referred to as Test 2.

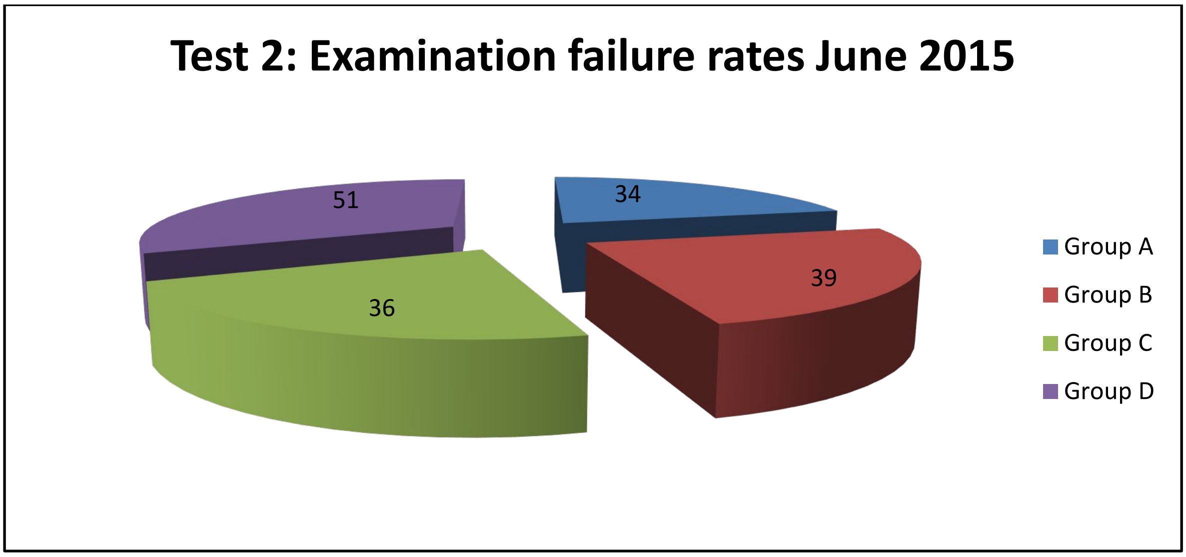


Figure 1.4: Term 2 Test 2 QT failure rates

Figure 1.4 shows failure rates. There is a 14 % decrease in the students' pass rates. The decrease indicated in the students' failure rates of the June examination demonstrates a positive correlation between the increased student failure rates and the decreased student pass rates.

Figure 1.5 illustrates the performances of the four groups in both Test 1 and Test 2.

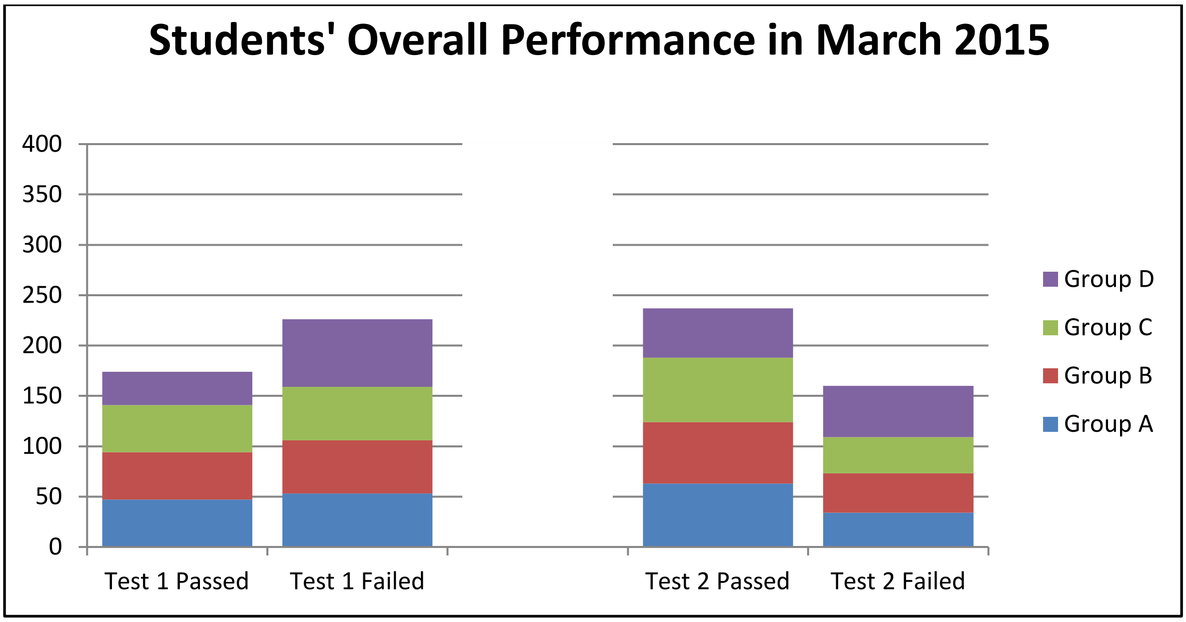


Figure 1.5: Student achievements

Figure 1.5 demonstrates that the highest failure rate in the HCINCT programme at the end of Term 1 occurred in the research participants representing Group D. The composition of all the student groups within the HCINCT programme was a fair blend of students. Regarding the entire group of students, eight percent of students had studied pure Mathematics at high school, 4% of the students studied IT and engineering subjects at TVET colleges prior to joining the HCINCT programme, 86 % of students had studied Mathematical Literacy at high school and the remaining 2 % comprised students who had taken a year off to do things other than study or work.

Group D consisted of students who had studied Mathematical Literacy and had passed their matriculation examinations with poor symbols. Group C had the highest number of students who had studied pure Mathematics in their matriculation studies. Students in Group B comprised students who had studied Mathematical Literacy and students who had studied other quantitative subjects for matriculation.

Group A consisted mostly of students who had studied IT at FET colleges and at high school. Some students belonging to Group A had worked as junior IT technicians in the IT fraternity prior to pursuing their HCINCT studies. Eighty-eight per cent of the students who were allocated places in Group A had conducted their high school studies at private schools in South Africa. Figure 1.6 demonstrates the pass and failure rates for all four student groups at the end of their mathematics intervention programme through QT class tutorials in the HCINCT programme in 2015.

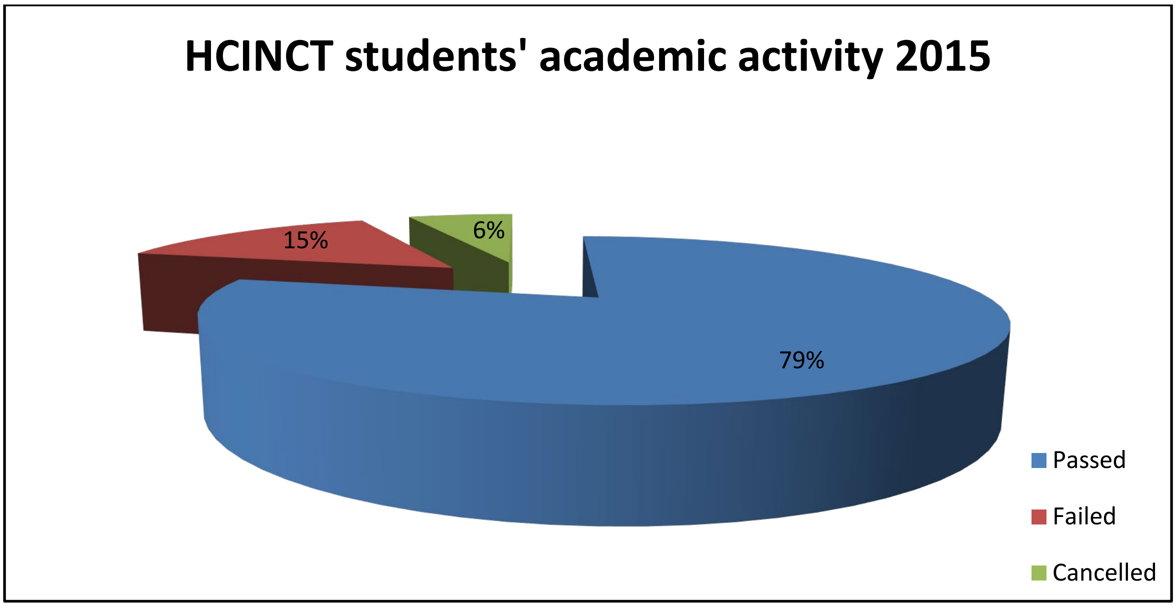


Figure 1.6: Students' mathematical capabilities at the end of the intervention

Figure 1.6 illustrates learner retention and throughput rates at the end of the intervention in November 2015. Students entering their first-year university studies mathematically underprepared is not exclusive to the UoT under study or to South Africa. The world in general is concerned about the poor performance of engineering students, particularly in regard to differential calculus computation by first-year students at UoT's. In the current study, most students failed their first summative assessments. The highest percentile of student failures was among Group D students.

However, this high failure rate in Group D was structured. For this study, the first 105 spaces were allocated to groups A, B and C, with 35 seats per group. Initially 20 seats were allocated to students in group D. The remaining 22 seats were allocated to Group D. These were seats reserved for students that joined the MCI late. For this study, students were allocated to a group based on receipt of their application and their meeting the criteria stipulated by the UoT for admission into IT programmes.

Early applicants were evened out so that there was diversity in the groups. The seat allocation system used in the IT Department of the UoT under study is that Group D is filled to 50% capacity (20 seats) at inception of the intervention for enhancement of mathematics capability. The remaining 50% (20 seats) are filled by students who register late or students who are on the waiting list. During the intervention, the remaining 50% of students joined Group D at different intervals. Eighteen students joined the group between the beginning of March and the middle of March. The last two students joined Group D on 16 March, a mere two days before the administration of the first summative assessment for Term 1 of 2015.

1.3.9 Pilot year versus year one

Figure 1.7 depicts the average percentage pass rates of students for the years 2014 and 2015. The year 2014 was a pilot study that was conducted informally and pegged onto the IT diploma programme of that year.

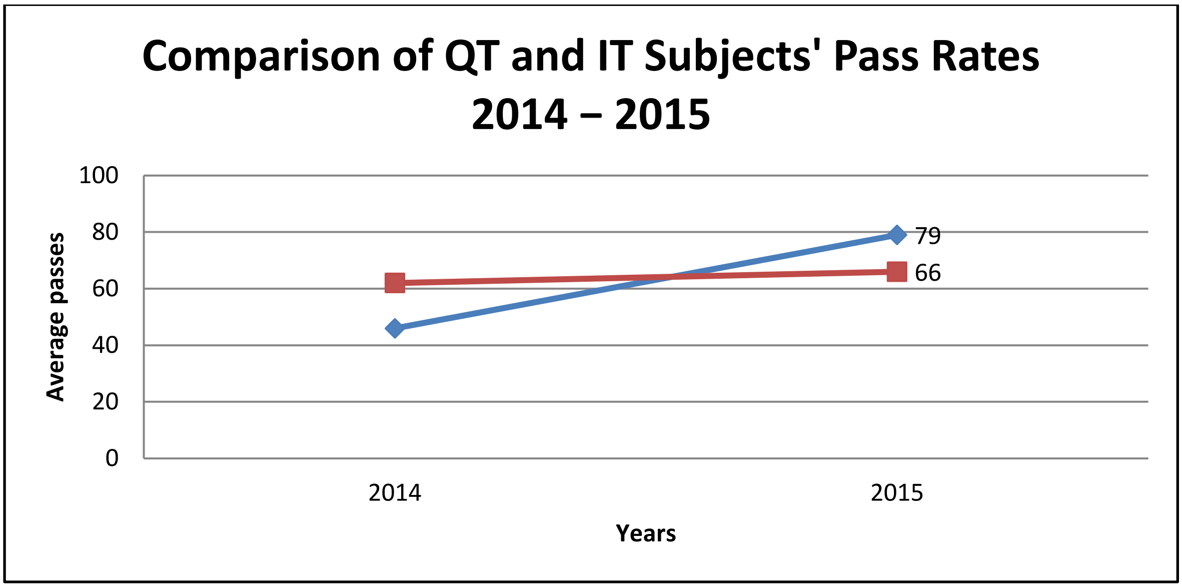


Figure 1.7: Comparison of throughput rates between pilot year and year one

The results of seven IT courses were averaged to obtain the percentage pass rate for students who started their IT diploma in 2013 and completed it in 2015. These pass rates were then compared with the QT pass rates for the same years to determine whether any trends emerged in the HCINCT pilot interventions that were implemented in those years. Although the comparison of these students to the 2015 IT freshmen is slightly skewed, one does get an insight into the mathematical capabilities and the trajectories of the IT courses.

The 2015 students attained a 79% pass rate for the QT course compared with the 46% pass rate of students who studied QT in 2014. This demonstrates a 33% increase in the students' pass rates for the year 2015 when compared with 2014, the pilot year for the QT course. The pass rate average for the combined IT subjects in 2014 was 62% and in 2015, the pass rate average was 66%. This showed a 4%

pass rate increase in 2015. The question is could the QT pass rate have contributed to the student pass rates? Table 1.5 shows the individual IT courses that were grouped together to determine an average pass rate for the IT courses in the pilot year (2014) and in the intervention year (2015).

Table 1.5: Pass rates for IT subjects in 2014 and 2015

Subject	Pilot	HCINCT	Difference
Computer Applications 1	70	28	– 42
Computer Hardware	67	64	– 3
Computer Networks	48	64	16
Computer Software	56	52	– 4
IT Service Project 1	53	96	43
IT Service Practice 1	63	99	36
IT Services Theory 1	76	59	– 17
Average percentage	**62**	**66**	**4**

Table 1.5 shows inconsistencies between the two years in regard to the students' pass rates in the individual IT courses. Therefore, it is difficult to assess if the MCI had an influence on the students' pass rates. There was an overall 4 % increase in the students' pass rates for the combined IT courses for 2014 and 2015, as shown in Table 1.5.

Figure 1.8 shows students' throughput rates in the IT diploma programme over a three-year period.

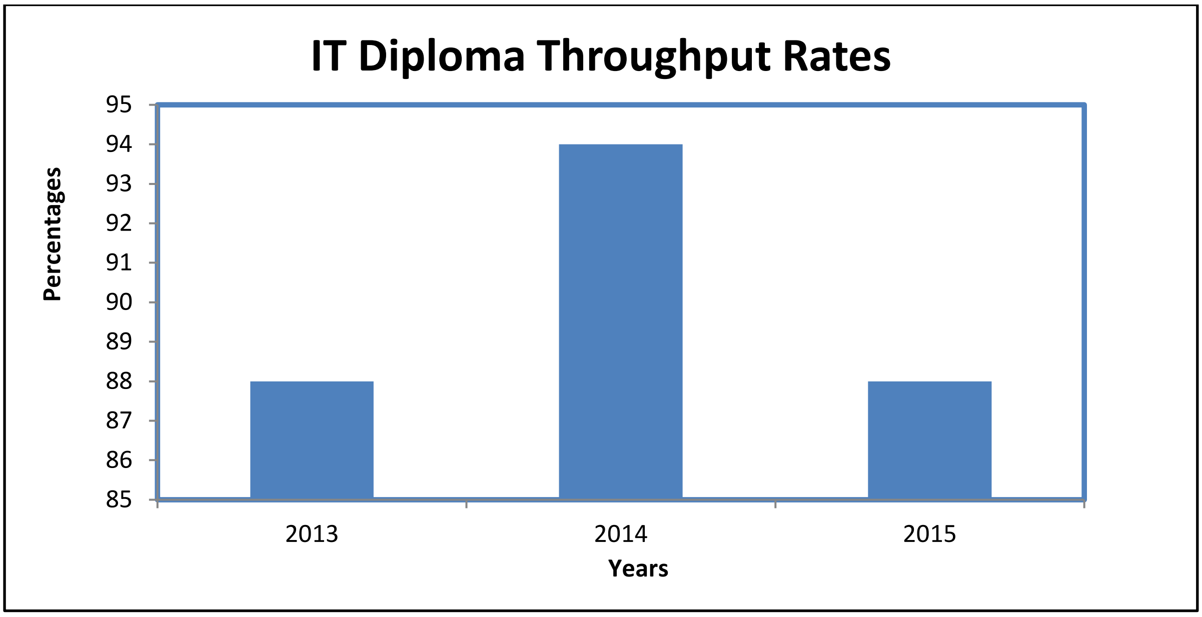


Figure 1.8: Throughput rates of IT National Diploma students

Figure 1.8 above displays the overall throughput rates for the students who entered their IT diploma studies in 2013 and exited in 2015. An IT foundation course was run informally with low student numbers under a separate name in 2013. The students' results in the foundation course of 2013 were included in the IT National Diploma due to the size of the pilot programme (Higher Education Data Analyzer, 2016). The students' throughput rates remained the same at the end of year one (2013) and year three (2015). However, year two (2014) showed a 6% increase in throughput rates.

1.4 LIMITATIONS OF THE STUDY

The limitations that are presented in this section were pivotal to the investigation.

1.4.1 Methodological limitations

A survey questionnaire that was administered to 180 students was omitted from the study because the IBM SPSS reliability analysis scale showed that the 15 items on the scale were unreliable with a Cronbach's alpha of .296. Iterative ADDIE was used as a process model since it could not be used as a conceptual framework because it does not have all the elements required to meet this study's conceptual framework requirements. The interpretive findings in the study were analysed manually. Perhaps if qualitative software were used, more constructs might have emerged from the student responses.

1.4.2 Contextual limitations

This investigation does not try to establish the causes of the students' mathematical under preparedness and it does not assume that all UoT studies require participants to have a strong foundational arithmetic background. In addition, the study does not claim to have a solution to enhancing students' mathematical capabilities.

1.4.3 Practical and logical limitations

Practical limitations of the study included constraints that limited the interactions with interviewees to one hour per person. There were also logical constraints, which were particularly apparent when compiling a similar pre-test for the HCINCT programme students of 2016.

1.5 DELIMITATION

The study is limited to students who were registered for the HCINCT programme in 2015. The students from the HCINCT foundation programme of 2016 were not interviewed regarding their mathematical capabilities since these students were not the focus of the current study. However, it could have been beneficial to compare such findings with the 2015 assessment scores when pursuing answers to the research question regarding the circumstances under which the students' results improved.

1.6 SIGNIFICANCE OF THE STUDY

This study should benefit other lecturers within the UoT who find a study of this nature relevant and beneficial to their needs. In addition, this study is valuable to other academics, students in other UoT's, other institutions of higher education, government entities and government employees in the Department of Higher Education in South Africa. This study should have value to persons whose line of investigation is in the same or a similar arena as this study.

This research is necessary because through the enhancement of the mathematics intervention programme, the subject of QT was streamlined so that its offerings met the needs of the participants. The learning materials were created, tried and continuously modified during year one of this investigation. The modified interventions were used for the student intake of year two and lessons were learnt through interaction with the research participants.

The feedback received from stakeholders in the HCINCT programme resulted in a co-authored quantitative techniques book called *Information Technology Services Management Quantitative Techniques*. The book was piloted at TVET colleges in 2017 and has since been in use in the HCINCT programme. The HCINCT programme was passed to the TVET colleges in 2017 as was intended when the HCINCT programme was piloted by the UoT.

1.7 SUMMARY OF THESIS CHAPTERS

Chapter 1 of this thesis presents the purpose for conducting the study. The justification for conducting a study with the aim of increasing students' throughput rates for the IT diploma course and thus increasing employability for IT students in the IT arena is also presented in this chapter (Alexander, 2013). This is followed with an overall view of the different elements that were used in pursuit of answers to the research questions and the subsequent solving of the research problem. These elements were, inter alia, the problem statement, the research problem, research questions, research objectives, research methodology and the research paradigm. Limitations of the study are presented and the need for this study to be conducted is explained. Chapter 2 provides a background for the study, contextualizing its key elements. An overview of the QT course is given and its role in enhancing the mathematical capabilities of people deemed to be in need of mathematical skills is demonstrated by a test administered to the IT freshmen before the QT class tutorials. The QT intervention administered to the IT freshmen who volunteered in 2015 is outlined.

Mathematical interventions undertaken nationally in South Africa (Bozalek, Garraway and McKenna, 2011) to allow epistemological access by people who may not have been granted access to university studies because of their mathematical abilities are bought forth in a debate. Chapter 3 begins by outlining the process that was used to locate sources of information. A debate around mathematical interventions conducted by universities globally is presented (Worthley, 2013; Ford, 2015). The selection of the literature materials to be reviewed is presented and the critical literature review strategy is discussed.

A list of top ten authors is presented in a table for the reader/s of this thesis. These authors were chosen through a stringent process in which their notions were critically reviewed and used to argue from different standpoints for and against the efficacy of the enhancement of the mathematical capabilities of first-year university students. In the literature review, the researcher grouped authors with similar views while using authors with contesting views to argue against popular and unpopular perspectives regarding the topic of this study.

Two literature reviews were conducted (Chapter 3) in order to source literature that supported the data that emerged from the students' one-on-one interview responses. Eight categories emerged from the literature reviewed: (a) poor performance; (b) mathematical capability; (c) mathematical ability; (d) knowledge acquisition; (e) mathematics anxiety; (f) alignment; (g) self-efficacy; and (h) attitude. Chapter 3 uses the theoretical framework of Kolb (2015) as a lens to report on the efficacy of the enhancement of the 2015 HCINCT programme at a UoT in South Africa. The iterative analysis, design, development, implementation and evaluation (ADDIE) model was used as a process model for the mathematics intervention tutorial classes though the subject of QT in the HCINCT programme (Branson, 1978; Berkowitz and O'Neil, 1979; Molenda, 2003).

In Chapter 5, the demographics of the sample group are briefly discussed. This is followed by a narrative on the findings in which each research question is presented and a tentative answer and the literature review that supports or refutes the tentative answer is furnished. Chapter 6provides synopses of this investigation and recommendations and conclusions are made. Answers to the research questions are presented. Scientific, political and educational contributions of this study are discussed.

2 CHAPTER 2: BACKGROUND

2.1 ABOUT TIMSS

The TIMSS plays many roles in mathematics and science education of learners in the United States of America in comparison with learners in other countries. Data comprising learners' TIMSS assessment scores have been used to improve the parity of educational aftermaths (Baumert, Kunter, Blum, Brunner, Voss, Jordan, Klusmann, Krauss, Neubrand and Tsai, 2010; Borman and Dowling, 2010). One of the roles of the TIMSS is to provide reliable and timely data in the education sectors (National Council of Teachers of Mathematics, 2006). In 2011, a TIMSS was internationally conducted and Grade 8 test-takers from 50 countries were assessed.

Countries used the information gathered from the test results to identify school elements that reduced the relationship between socio-economic status and achievements. Mathematics teachers are expected to transfer mathematics epistemology to their pupils through teaching (National Centre for Education Statistics, 2011) Mathematics education in South Africa is low due poor mathematics teacher education and to a learning gap at primary school level (Mogari, 2014; Takane, Tshekane and Askew, 2017).

The mathematics mean for South African Grade 8 test-takers in the 2011 TIMSS international assessment was 353, which fell below the 500 mean for the test-takers from countries that had students who scored high. Overall, the South African test-takers attained the 48th position in the 2011 Grade 8 TIMSS international assessment.

Table 2.1 displays the learners' test scores for the 2011 TIMSS.

Table 2.1: Mathematics mean of test-takers by country

	No. of Schools	No. of Students	Math. Mean	Math. SD
	Samples		Mathematics Achievement	
Ghana	161	7323	333	85
Honduras	155	4418	338	76
Hong Kong, SAR	117	4015	584	84
Japan	138	4414	569	84
Korea	150	5166	611	89
Morocco	279	8985	372	85
Oman	323	9542	367	106
Russia Fed.	210	4893	539	80
Singapore	165	5927	610	83
South Africa	285	11966	353	85

Table 2.1 illustrates countries that participated in TIMSS assessments. The data gathered from TIMSS assessments are used to improve the capability of mathematics teachers. South African Grade 9 learners participated in an international assessment conducted by TIMSS in 2011. The average age of learners who participated in the assessment was 16 years. The sample was drawn from 285 schools and 10 085 pupils participated. The mathematics mean attained by South African test-takers in the Grade 9 TIMSSS test in 2011 was 275. This mean was below the 500-mean attained by an average test-taker in Singapore, a country with the highest learner test scores.

Table 2.2 below displays the TIMSS scores for South African Grade 9 students in 2011.

Table 2.2: Achievements of South African Grade 9 test takers (TIMSS SA, 2011)

Indicator	Mathematics	Science
Average achievement (standard error) International benchmarks	351.9 (2.5)	331.6 (3.7)
% Learners below 400	75.5	74.8
% Learners at or above 400	24.5	25.2
% Learners at or above 475	8.5	11.0
% Learners at or above 550	3.1	4.4
% Learners at or above 625	0.6	1.2

The international standards benchmark in the scores was $\approx$ 500. However, the benchmark varies from year to year depending on the overall performance of the top scorers (Howie, Marsh, Allummoottil, Glencross, Deliwe and Hughes, 2000) Labels in the first column of Table 2.2 depict TIMSS's test prediction levels for average achievements of test-takers in Mathematics and Science. In this instance, any score below 400 is considered weak, and learners who achieve a mark greater than 625 are above the international average score of 500. Overall, South African students performed badly even when compared with learners' test scores from countries on the African continent.

Figure 2.1 presents South African assessment of 2011.

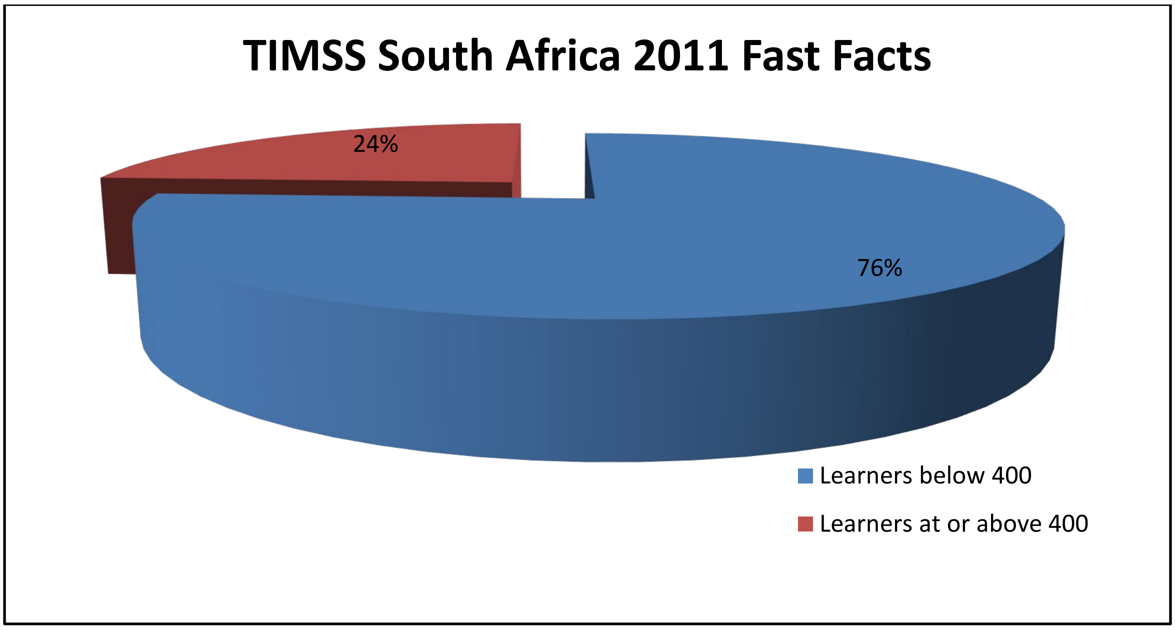


Figure 2.1: Test scores of Grade 9 test-takers (TIMSS SA, 2011)

Figure 2.1 demonstrates South African students' scores for the 2011 Grade 9 TIMSS test. The mean test scores were regarded as being among the lowest student scores in the entire test. The following section discusses mathematics interventions that were conducted at the UoT where the current study took place. This was done to showcase the need for more studies to be conducted at the UoT; to ensure ease of access to documentation of existing studies for internal use; to build internal capacity so that resources can be maximised; and to empower lecturers through collaborative learning derived through learning from each other's work and thus avoiding duplication.

2.2 WITHIN THE UNIVERSITY OF TECHNOLOGY

Departments within the five faculties of the UoT where this study was conducted implemented their own mathematics augmentation interventions in an effort to deal with the low level of mathematical skills in students transitioning from high school to university (Brandell, Hemmi and Thunberg, 2008). A four-month extended attribution intervention programme designed to modify students' views of their intellectual inability to grasp mathematical concepts was implemented for first-year design students at the UoT (Rohlwink, 2015). In her study, Rohlwink (2015) showed that students' anxiety towards mathematics hindered their ability to acquire mathematical capabilities.

Hence, Rohlwink's (2015) study focused on ensuring that the students' anxiety towards the subject of Mathematics was first addressed through an intervention programme. Another effort to enhance mathematical capability at the UoT was conducted by the Department of Engineering. Three engineering departments used one mathematics intervention programme that was run by one instructor. The mathematics intervention was conducted over a one-year period. The intervention focused on the zone of proximal development in the learning of differential calculus among engineering students in the foundation programme at the UoT.

A new programme called the HCINCT qualification was created, with its focus on IT service management (Alexander, 2013). In 2013, four colleges in the Further Education and Training sector (FET) and the UoT under investigation united to form a consortium to launch the process. In 2014, the IT Department at the UoT conducted an informal pilot study in agreement with government (DHET, 2013). The trial for the HCINCT foundation programme was not a stand-alone project; it was pegged to the IT diploma. The HCINCT foundation programme was expected to produce appropriately prepared students for enrolment into the Diploma in ICT programmes at the end of the HCINCT programme.

Therefore, engagement was expected to improve throughput rates and access opportunities at the UoT in accordance with the requirements of Minister Nzimande's *Green Paper for Post-School Education and Training* (Education, 1995; DHET, 2013). Professor Alexander, Head of Department in the Faculty of Informatics and Design employed the researcher to conduct this investigation in January 2015.

2.3 CRITERIA FOR STUDENT ADMISSION TO UNIVERSITY OF TECHNOLOGY

Using students' matriculation results, the UoT applies its own APS to admit applicants into the first-year IT streams. Students who attain a total average score of less than 36 points but attain an average score of between 28 points and 35 points are accepted into the one-year foundation course in ICT. However, each student application is taken on its own merit. Figure 2.2 shows the required percentage scores for students who want to gain acceptance into either the IT diploma or the higher certificate of the ICT programme.

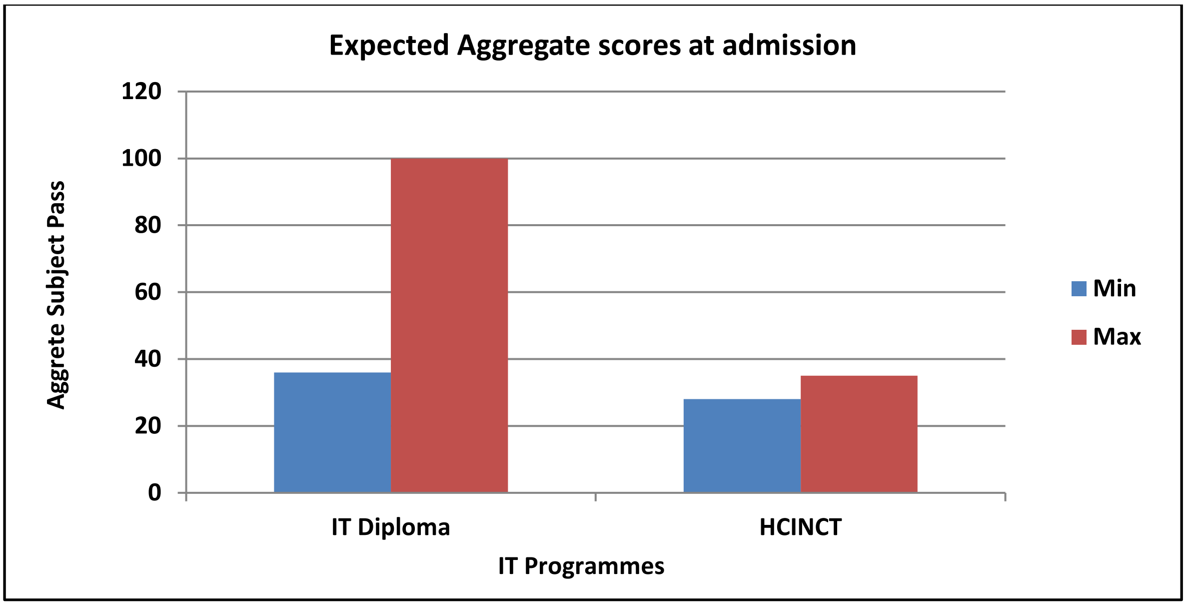


Figure 2.2: Required matriculation scores

Figure 2.2 relates to the aggregate scores of students' matriculation results that comprise passes in six matriculation subjects of which a pass in high school mathematics is a prerequisite for admission. Students who study Mathematics Literacy for matriculation are suitable candidates for the HCINCT foundation programme. In the 2015 HCINCT group, there were ≈ 8% of students who had taken pure Mathematics in their last years of high school but had passed with a weak mark. In addition, their overall mark for entry into the UoT fell below 36 points when accessed using the APS of the IT Department.

2.4 HIGHER CERTIFICATE IN INFORMATION AND COMMUNICATION TECHNOLOGY PROGRAMME

Class tutorials in the subject of QT are built upon the QT course scope. Students can study on their own and practise both on and off campus in preparation for their QT class tutorials. For the 2015 HCINCT programme, lecture notes, class materials and preparatory tutorials were placed on the university's learner management system (Blackboard). A prerequisite for attending the QT class tutorials was that students studied and completed preparatory exercises at home or off campus before attending class tutorials. This allowed for the transformational and transactional acquisition of mathematical knowledge (Meltzer, 2002).

In return, students presented problems of difficulty for group discussions. If the group failed to solve the problem, the lecturer became involved and solved the mathematical problem with the students. Visualisation of mathematical theories through gamification was one of the models used to transfer mathematical knowledge to the students. The class tutorials were not for marks. Learning materials were created using content that was familiar in students' everyday lives for ease of conceptualisation. Table 2.3 displays the QT course content for 2015.

Table 2.3: Composition of Quantitative Techniques course

Scope	Objectives	Duration	Skills	Sources
Semester 1: Operational mathematics for IT	Scaffold learning; Acquire knowledge	16 weeks	Foundational Application	Books, videos and simulation
Semester 2: Basic algebra and probability	Acquire knowledge; Build logic reasoning	8 weeks		
Semester3: Basic calculus and MS Excel group project	Acquire knowledge; Demonstrate knowledge	12 weeks		
Semester 4: Basic maths and statistics for business use (QT)	Problem-solving; Interpretation	3 weeks		

Table 2.3 demonstrates the QT course content on which the QT class tutorials were built. In early February 2015, 147 IT students entered the HCINCT intervention programme for the enhancement of mathematical capabilities. The first pre-test was set at the South African Grade 12 level. The test was constructed using past matriculation examination papers (Western Cape Government, 2013). The students voluntarily agreed to participate in the pre-test, which was administered to the research participants on 3 February 2015. The topics in the pre-test were from an assortment of questions obtained from the 2014 matriculation examination paper that was checked for alignment against a South African matriculation mathematics prescribed book (Aird *et al.*, 2013).

The assessment questions included operational mathematics, basic algebra, basic calculus, Euclidean geometry and basic statistics. The assessment was conducted to set the QT class tutorials, to understand the students' mathematical needs and to construct knowledge (Hargreaves, 2005; Seaman, 2011). Designing the assessments for the mathematics interventions and testing the students' mathematical skills using multiple-choice questions were explored. Testing the students' foundational arithmetic skills/operational mathematical skills using pencil and paper questions was also researched, explored and testing with pencil and pen was chosen.

Finally, a decision on how the assessments would be administered was made (Ohlsson, 1992; Schoenfeld, 2000; Artigue, Kirchgraber, Hillel, Niss and Schoenfeld, 2002; Schoenfeld, 2007; Schoenfeld, 2013).Assessment theories were checked to minimise the notion that classroom assessment activities promote or impede leaners' acquisition of mathematical capabilities (Bennett, 2011). Approximately 92% of the 74 research participants failed the first pre-test that was set at matriculation level. A second pre-test set at a Grade 10 level was administered to the students on 2 March 2015. The assessment tool had to be educational for both students and the lecturer.

The new assessment tool shifted from being teacher-centric to being student-centric (Wismath, 2013) while bearing in mind the needs of the students, teachers and the UoT. Collaborative learning was used to promote positive learning behaviours through the assessments (Torrance, 2007). Approximately 80% of the students who volunteered to take the second pre-test failed the second assessment. A third pre-test set at Grade 6 level was administered to the research participants on 16 March 2015. The decision to set the third pre-test at a Grade 6 level was because the students' assessment scores in both the previous pre-tests had shown a trend that the students' foundational arithmetic skills may be the cause for the students' poor performances in the previous two pre-tests.

Pre-tests were conducted because the information about the learners' mathematical capabilities was fundamental to the implementation of the MCI using the iterative ADDIE as a process model (Howie and Plomp, 2002; Van den Akker, Bannan, Kelly, Nieveen and Plomp, 2013). The students did not have aiding materials such as calculators and formula sheets. Prohibiting students from using calculators and formula sheets was to gauge the students' mental arithmetic skills. Early development of mental arithmetic skills reduces the anxiety to learn mathematics and helps learners to develop the mathematical capability needed for scaffolding in later years (Ramirez *et al.*, 2016).

The prohibition of aiding materials was also to gauge students' understanding and knowledge of foundational arithmetic/operational mathematics (Braun and Bily, 2013; Ludvigen *et al.*, 2016) in addition to gauging students' application of their foundational arithmetic/operational mathematical skills to solve simple mathematics problems. First-year IT students enrolled in the HCINCT programme are expected to attain a 65% overall aggregate mark to be guaranteed a place among the top 20 students of the IT diploma course the following year. Therefore, it was important to know the level of foundational arithmetic skills that the research participants possessed on entry in order to compile learning materials that would focus directly on the missing skills.

University pre-courses that are used to enhance the mathematical capabilities of students entering university studies with weak mathematical abilities are built upon other major courses that support students (Parsons, 2005; Worthley, 2013; Ford, 2015). This was applicable to this study because of time constraints and the fact that the QT class tutorials were pegged on seven core IT subjects that required students to possess feasible foundational arithmetic capabilities upon which to scaffold IT knowledge by May to June of the same year.

3 CHAPTER 3: LITERATURE REVIEW

This chapter examines existing knowledge of mathematics interventions conducted at various universities. The literature reviewed showed that institutions of higher education conducted these interventions to enhance the mathematical capabilities of first-year IT students who entered their university studies mathematically and numerically underprepared for university studies that require a firm grasp of basic arithmetic, pre-calculus and basic algebra in its participants (Doyle, Kasturiratna, Richardson and Soled, 2009; Locklear, 2012; Shin, 2013; Ford, 2015).

Literacy in mathematics is an individual's capacity to formulate, employ and interpret mathematics in a variety of contexts. Azevedo, (2014), Azevedo and Aleven, (2013) and Greene and Azevedo, (2010) suggest that technology fosters students' metacognitive or self-regulated learning. Therefore, acquiring literacy in mathematics includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena (Programme for International Student Assessment, 2015). Literacy in mathematics assists individuals in recognising the role that mathematics plays in the world.

Therefore, being mathematically literate allows one to make the well-founded judgements and decisions that are needed by constructive, engaged and reflective citizens. Mathematical language is a significant predictor of numeracy performance (Purpura and Reid, 2016). The students of today use (ICT) comfortably to acquire productive and strategic competence and cognitive skills (Junco, 2012; Calvani, Fini, Ranieri and Picci, 2012; Gu, Zhu and Guo, 2013).

Some authors posit that University students are digital natives and often engage in the use of ICT (Hall, Ponton and Hall, 2005; Moylan, 2009; Ting, 2015). The literature reviewed showed that students use learner autonomy when they study on their own, acquire skills in self-directed learning and exercise accountability for their actions towards acquiring knowledge.

3.1 CHAPTER STRUCTURE

This chapter begins with an analysis of the gap that gave rise to the investigation. An outline of the analysis of the process used to find sources for the literature review is presented. This is followed by a discussion on the method that was used to select and record or exclude literature-reviewed material. The objectives and the questions that guided the literature reviewing process are presented to the reader. The eight key constructs that emerged from a combined first and second literature review are also presented. A list of the top key writers is included.

Thereafter, the students' assessments scores were categorised so that there would be a range of assessment scores, for example, high-range marks, middle-range marks and finally, the low range of student's performances. The script of Student 4 was randomly selected from the assessment scripts of students that received the highest marks.

GAP ANALYSIS

Firstly, an initial investigation was conducted to establish why some interventions were successful while others were not. Secondly, detailed aspects of the interventions were documented. This process categorises reviews according to focus, goal, perspective, coverage, organisation and audience. Thirdly, notes describing the minimal focus on mathematics literacy and interventions for first-year IT students at all universities, not only the UoT in which this study was conducted were taken. Finally, the researcher realised that there is limited work that foregrounds the enhancement of mathematical capabilities for mathematically, numerically and/or quantitatively underprepared students who enter tertiary education for the first time.

The study used mathematical capability opposed to literacy of mathematics or quantitative literacy. The literature demonstrates that there is a significant amount of work conducted in addressing the mathematical capabilities of underprepared students at high school and primary school level (Värgrynen, 2003 Gustafsson, 2005; Gustafsson, Nilsen and Hansen, 2015). However, the researcher recognised that the bulk of the work done was conducted at primary school level, which is confirmed by Bonne and Johnston (2016). The researcher aims to contribute towards minimising this gap in academic writing. In addition, a debate concerning mathematics interventions conducted globally and in South Africa is presented to the reader (Brandell, Hemmi and Thunberg, 2008).

3.2 THE INTERNATIONAL CONTEXT

Literacy in mathematics is an individual’s capacity to formulate, employ and interpret mathematics in a variety of contexts. Literacy in mathematics includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. Literacy in mathematics assists individuals in recognising the role that mathematics plays in the world and in making the well-founded judgements and decisions that are needed by constructive, engaged and reflective citizens (Organisation for Economic Co-operation and Development (OECD), 2008; and OECD, 2013)

Mathematical capabilities are key to understanding cause and effect, to self-efficacy, to fostering understanding of quantitative tools and to managing and solving problems in practice (Purpura and Reid, 2016). An ongoing international debate suggested that developing countries should enhance their technological abilities to enable their people to create new products and new services for commerce and technology (Khayyat and Lee, 2015). Mathematical capabilities often refer to capacity building in acquiring IT skills and employability.

The (World Economic Forum, 2016) asserts that progress in technology and speed in digitalisation are pivotal in transforming world societies, economic welfare and ways of doing business. The intercontinental deliberation also calls for the formation of an IT-focused tertiary education system that has its foundation on equipping students to learn to meet global competition through the creation of products and services that increase a country’s GDP(African Development Bank, Organisation for Economic Cooperation and Developmment, 2016) . A positive correlation exists between the student who enters university to study an IT programming course with strong mathematical capabilities and the student's ability to pass an IT programming course (Ford, 2015). Other authors' state that students should be taught logical mathematics and visual spatial skills so that they may learn the skills that they need most (Ghazi, Shahzada and Gilani , 2011; Gardner, 2013)

Therefore, mathematical capability in a nation is considered essential to the communities and the economic welfare of a country (Schwab, Sala-i-Martín, Brende, Blanke, Bilbao-Osorio, Browne, Corrigan, Crotti, Hanouz and Geiger, 2014). According to Schwab *et. al.* (2014) mathematical capability enables all nations of the world, not only developing countries (Khayyat and Lee, 2015). Globally, mathematical capabilities are needed (Altbach, Reisberg and Rumbley, 2009; Brown, 2010 (Fritz and Koch, 2016 World Economic Forum, 2016).

3.3 SOUTH AFRICAN CONTEXT

According to Dr Andre Van Zyl, Director of the Academic Development Centre at the University of Johannesburg, South African universities had a dropout rate of between 50% and 60% in 2015. In South Africa, the debate is about capacitating learners with an IT-orientated education system that equips its recipients with ICT information literacy competences and good information literacy savvy that is coupled with good mathematical competence since these aspects are integral to successful IT education for IT students (Rader, 2002; Department of Basic Education, 2016).

The South African schooling system is constantly under tremendous pressure due to the deteriorating matriculation pass rates, particularly in the science-orientated subjects such as Mathematics (Calitz, 2010). South Africa should develop a higher education system that connects the country globally since nowadays, countries are visually connected through technology and South Africa should focus on this

(Maharaj, 2005). A description of the processes used to source literature-reviewed materials for the investigation follows.

3.2 MOTIVATION FOR THE LITERATURE REVIEW

There is a need to conduct this investigation because there is limited literature regarding the subject of the study at university level (Van de Mortel, Whitehair and Irwin, 2014). The epistemological transfer of mathematical capabilities by educators and the insurmountable epistemological acquisition of mathematical capabilities by primary school learners (Gustafsson, 2005; Gustafsson, Nilsen and Hansen, 2015) affect pupils following the curriculum at higher grades, especially in subjects vertically demarcated such as Mathematics and Science. Intervening early to prevent, diagnose and correct these learning deficits is the only appropriate response (Spaull, 2013).

It was determined that interventions have been conducted at the UoT under study, at other UoT's, at traditional South African universities and in various government departments (Bozalek, Garraway and McKenna, 2011). However, a consolidated strategy that documents details on exiting interventions was not found. An effort was made by Bozalek, Garraway and McKenna. (2011) whereby a few interventions were documented in a case-study format and published as a book. The case studies were brief but concise and they gave adequate information for the reader to understand the efforts made.

However, pertinent information needed to gain true insight into the results of the intervention and the recommendations for future studies was inadequate. Therefore, due to the limited amount of information in regard to the interventions, the documented case studies were inadequate and hence, answers to the research questions and solutions to the research problem were not found in the documented case-study interventions.

3.2.1 Process used

The electronic and physical libraries of the Cape Peninsula University of Technology (CPUT) were used to search for dissertations, theses and bibliographies of known and lesser known authors on the topic under study, using CPUT (2016), Nexus, Trove, Phd.data.com, Sciences and Sabinet databases. The study followed the literature review style of a graduate thesis (Okoli and Schabram, 2010). The literature review process incorporated objectives and questions, which kept the reviewing process focused (see Table 1.1). The literature review was conducted through searching primary and secondary information sources.

The guidelines of known authors in writing literature reviews were used to gain methodological insights, delimit the research problem, avoid fruitless efforts and identify recommendations for future research in the researched interventions (Gall, Borg and Gall, (1996); Hart, 1998). Data were gathered concurrently for both the qualitative and quantitative methods (QUANT + QUAL) used in the study (Morse, 2003) During qualitative data collection, some constructs emerged, resulting in a second literature review being conducted in search of a framework to prove or refute the newly discovered concepts (Levy and Ellis, 2006; Okoli and Schabram, 2010).

Qualitative and quantitative data collections were conducted in order to gain the advantages of both approaches so that ultimately, answers to the research questions could be obtained and a solution to the research problem could be found. Literature reviewed was used to validate assumptions made by the students during their one-on-one interview responses (Randolph, 2009). In addition, the literature reviewed was used to build theory. The qualitative approach has advantages, but it also has limitations (Willig, 2008).

One of the advantages of using qualitative methods is that the method affords a researcher a purposeful chance to study the meaning of the phenomenon at hand (McLeod, 2001). Although the qualitative approach facilitates the creation of authentic novel insights and new comprehension, qualitative methods limit the researcher in recognising generally applicable laws and causes and effects in a study. The purpose of conducting qualitative research is to discover variables rather than trying to control variables as one does in hypothesis testing research. Qualitative research is conceptual thinking and is fundamental to theory building while the use of a quantitative research method, inter alia, is used to test the relationships between various hypotheses and to deduce their impact on each other. Thus, using both methods captures the good from both approaches. Keywords used to search for literature included backward and forward searching of the keywords. The following paragraph lists a few of the combinations that were used to search for literature for the investigation.

3.2.2 Keywords searched

The following keywords and variations thereof were used:

Enhancing mathematics capability + first-year IT students, remedial programme and mathematics skills, Computer science studies + Maths education, Mathematics + numeracy + quantitative techniques enhancement for underprepared first-year IT students, First-year IT students + entering first time university studies + mathematics underprepared, increasing numeracy skills for first-year university students, applied numeracy skills + needed + computer science studies, foundation year studies +mathematics interventions + University, extended programme for acquiring maths skills

3.2.3 Sourcing

The Programme for International Student Assessment (PISA), (2013) suggests that the type of mathematical processes and the mathematical capabilities that students acquire from their literacy in mathematics equip the students with tools that allow them to formulate situations mathematically. Students should possess the capabilities to employ mathematical concepts, facts, procedures and reasoning in order to connect and interpret the problem and ultimately, to apply and evaluate mathematical outcomes (Värgrynen, 2003). From the literature reviewed, the researcher determined that some interventions had the ability to help participating students acquire mathematical attributes (Bozalek, Garraway and McKenna, 2011). The first step in obtaining the relevant literature entailed searching peer-reviewed journal articles published from 2011 to 2016.

Hence, the years 2011 to 2016 were purposely selected for seminal and current academic work. The focus of the journal articles had to be on interventions that were directed specifically at augmenting mathematical capabilities for first-year IT students at a UoT (Ford, 2015; Cēdere, Jurgena, Helmane, Tiltina-Kapele and Praulite, 2015; Rohlwink, 2015; Sheahan, While and Bloomfield, 2015). The search for literature progressed to looking for interventions in other areas of education, inter alia, engineering, computer science, mathematics, accounting, statistics, nursing and medicine.

Reference lists sourced from doctoral theses were assessed for relevance to the topic and if found applicable, were used to locate journal articles and occasionally, a book (Locklear, 2012; Ford, 2015; Applewhite, 2015). After searching all the avenues according to the researcher's standards, journal articles published earlier than 2011 were sought while holding true to the set benchmark for selecting articles. The next stage entailed searching for literature materials that focused on the same topic but were positioned at high school level (Putsoa, Dlamini, Dlamini and Kelly, 2003; Chisholm, 2005; Mamba and Putsoa, 2013; Vanbinst, Ghesquière and de Smedt, 2014; Cirino *et al.*, 2016; Hung, Chang and Lin, 2016).

Academic outputs mentioned in the investigation helped to put this research work into context. In Chapter 1, a claim was made that the level of mathematical capability of the research participants was below the level taught to Grade 6 pupils at primary school. Therefore, searching for interventions addressing the problem statement at Grade 6 was pivotal. The search produced interventions that were conducted at primary school level (Chahine, 2013; Desoete, Praet, Titeca and Ceulemans, 2013; Moore and Ashcraft, 2015).

3.2.4 Selection and recording

Once all the journal articles were selected, different authors' academic materials were rated according to their relevance to the study using record cards (Randolph, 2009). A follow-up literature review rating was conducted using databases to establish how researchers had cited a particular author's work. The selected journal articles were read and their methods and findings were summarised and entered into a table that demonstrated articles with similar topics, foci and/or educational genre.

3.2.5 Selection of authors' views

The list of all read journal articles read was used to construct a list of the top ten writers identified from the literature reviewed. A follow-up selection was conducted by selecting authors according to the themes that emerged from the literature review. Authors with the same themes were grouped together and listed under the different constructs that emerged from the literature review (Randolph, 2009).

3.2.6 Excluding irrelevant literature

The exclusion of irrelevant literature was conducted in line with recommendations from known authors (Hart, 1998; LeCompte, Klinger, Campbell and Menke, 2003). The selected literature was once again examined and scaled down by checking if the chosen journal articles mentioned enhancing MCIs or not. Ultimately, only literature that indicated augmentation of interventions for mathematical capabilities proved relevant for the investigation. The literature reviewing process was guided by the literature reviewing objectives.

3.3 OBJECTIVES OF THE LITERATURE REVIEW

A literature review may be determined by several kinds of objectives. Table 3.1 provides an outline of a selection of objective types.

Table 3.1: Types of objectives

Objectives	Author/reference
Build a new theory or consider contrary findings	(Gall, Borg and Gall, 1996)
Search for research ability and applicability	(Creswell, 2013)
Check for practicability of the research	(Creswell, 2013)
Synthesise and gain a new perspective and identify new practices	(Hart, 1998)
Find variables in the literatures that prove or disprove the categories	(Moustakas, 1994)

The objective types outlined in Table 3.1 were used in conjunction with the literature review questions and the research questions that drove and positioned the study within the existing body of knowledge (Levy and Ellis, 2006; Okoli and Schabram, 2010). The following questions were compiled and used to assess each literature material. Literature with sufficient information on which to build was subsequently selected.

3.3.1 Literature review questions

The following questions are posed relative the conducting of literature reviews:

- Which interventions demonstrated successful implementation?
- Which interventions did not show successful implementations?
- What were the critical success factors for the intervention/s?
- What was the sample space for the intervention/s?
- What are the demographics of the sample?
- What were the methods for data collection, data analysis and data interpretation?
- How were the findings of the study presented?
- Who were the research participants of the intervention?
- Who sponsored the intervention and why?
- What were the criteria determining the choice of method?
- Where did the intervention take place?
- How were the results of the study presented?
- What are the future recommendations?

3.4 CONSTRUCTS

Figure 3.1 is a pictorial illustration displaying a list of all the constructs that were gathered through the literature reviewing process.

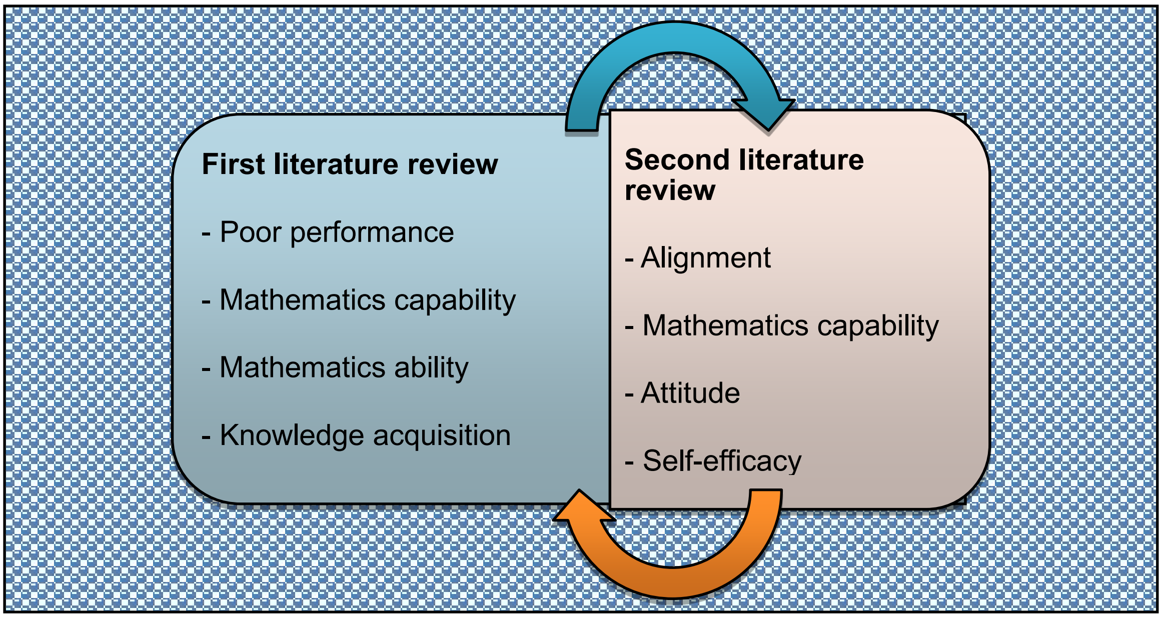


Figure 3.1: Conclusive list of constructs

Figure 3.1 illustrates that most authors of the reviewed articles used descriptive statistics, while a few authors used descriptive and inferential statistics to interpret and present their research findings. Observing methods used in research is fundamental to presenting research results to the reader/s. Checking that the results of the findings are reliable, valid, triangulated and generalizable back to the populations from which the sample group came is as important (Willig, 2008; Creswell, 2009; Merriam, 2009).

The investigation used the mixed methods approach for data collection, data analysis and data design and this allowed the study to gain positive attributes from both strategies (Tashakkori and Teddlie, 2003; Creswell, 2013). The mixed methods approach was found to be appropriate for the purpose of this study in augmenting each method's shortcomings. In the following pages, the top ten authors that provided relevant information to meet the needs of this investigation are presented. The method used for selecting these authors was based on the type of intervention on which their studies focused; the literature was checked whether the intervention was a mathematics intervention or other type of intervention. If the intervention was found to be irrelevant or if it were determined that the author provided insufficient information about the administered Mathematics intervention, a search for Physics, Accounting and engineering interventions was conducted. The process followed was firstly, a search for interventions that were conducted within a university and university students were used as the sample group.

Secondly, if there was insufficient information on the interventions conducted with university students as the sample group, a search was made for quantitatively inclined interventions that were administered to college students. Thirdly, if there were insufficient academic materials written on mathematics interventions and/or quantitative or numeracy-inclined interventions, a search was performed for literature regarding mathematics interventions that were conducted at high-school, middle-school and primary-school levels and that focused on my area of interest.

Regarding the choice of academic materials for Chapter 2, the literature review chapter, the sample size, the methods of data collection, the analysis, data presentation and the findings and conclusions of the studies were considered. Table 3.2 illustrates the top key writers selected by the researcher and the final constructs.

Table 3.2: Constructs, Categories and Sources

CONSTRUCTS								
SCAFFOLDING				COGNITION				
CAPABILITY	SELF-EFFICACY	ABILITY	PERFORMANCE	ATTITUDE	ANXIETY	ACQUISITION	ALIGNMENT	SOURCES
						■		Atmatzidou and Demetriadis (2015)
	■							Azevedo (2014)
							■	Baillie, Bowden and Meyer (2013)
■								Baxen, Nsubuga and Johansson Botha (2014)
	■							Bemacki, Nokes-Malach and Aleven (2014)
	■							Ben-Eliyahu and Linnenbrink-Garcia (2015)
	■							Binbasaran-Tuysuzoglu and Greene (2014)
			■	■				Bonne and Johnston (2016)
■		■						Cirino *et al.* (2016)
		■			■			Demirel, Derman and Karagedik (2015)
■								Efklides and Petkaki (2005)
■								Grenier-Boley (2014)
			■			■		Kezar (2013)
				■				Kwan and Wong (2015)
						■	■	Leung, Leung and Zuo (2014)
		■						Ludvigen *et al.* (2016)
	■							Motley and Locklear (2012)
							■	Psycharis (2016)
		■						Ramirez *et al.* (2016)
			■		■			Sandman (2014)
				■	■			Savelsbergh *et al.* (2016)
						■		Sheahan, While and Bloomfield (2015)
			■					Sung, Chang and Liu (2015)
						■		Ting (2015)
						■		Valiente-Barroso and García-García (2012)
				■		■		Wang, Guo and Jou (2015)

Table 3.2 demonstrates an overview of the concepts that were revealed during the search for the top ten authors while in pursuit of answers to the research questions and a solution to the research problem. In the following section, a discussion of each construct is presented in relation to the study's objectives, aims, research questions and research problem.

3.4.1 Poor performance

In 2006, the Government of New Zealand invested money and teaching resources to enhance the mathematical capabilities of learners in Grade 7 to Grade 9. Within a short time, 90% of teachers across the country had raised their teaching practices. The improvement in teaching practices resulted in an improvement in the students' mathematical capabilities. However, this success was short-lived and students returned to their bad performances in Mathematics (Bonne and Johnston, 2016). This poor mathematical performance of students was accredited to their teachers' inability to provide them with clear course content guidelines (Kezar, 2013; Mogari, 2014).

The opposition of Kezar (2013) suggested that students' poor performance in Mathematics could be attributed to the admitting personnel for mathematics courses at various universities. According to these authors, admitting personnel use incorrect variables to select students for first-year university courses that require Mathematics. Hence, the students perform poorly in their academic work and this affects their academic achievements in year one. Consequently, this non-performing trend is either carried into the subsequent academic years or the dropout rates increase. In the current study, the poor performance of students was attributed to the lack of early development in Mathematics.

Students need to realise and accept their missing mathematical skills and lecturers and teachers should facilitate epistemological access for these students (Rohlwink, 2015). Misalignment of the teachers' objectives for mathematics learning, the overriding department's curriculum development and objectives and the lack of creativity and innovation in the course content cause a disjoint in content, resulting in students' poor performance in Mathematic (Lakay and Alexander, 2012; Sung, Chang and Liu, 2015). The type of mathematics acquisition needed is the one that develops students' proficiency in critical thinking (Leung, Leung and Zuo, 2014).

Linking critical thinking skills to everyday life enables the real use of mathematics by students. In addition, students' positive beliefs about their mathematical capabilities are paramount to their good performance (Sangcap, 2010). Sangcap (2010) argues that students who had strong positive beliefs about their capabilities in the subject of Mathematics achieved good performances in the 2003 TIMSS world assessment. However, Grade 8 test-takers (aged 15 years) from the Philippines showed negative self-belief in their abilities to learn and to be successful in acquiring mathematical skills. According to Sangcap (2010), these negative self-beliefs resulted in the country attaining the 36th position out of 38 positions.

National examinations at the end of high school must align well with the curriculum expectations to form a valuable assessment of the mathematical capabilities acquired from learning targets (Leung, Leung and Zuo, 2014). However, despite the implementation of interventions to enhance mathematical capabilities of students who need them, other variables exist that affect students' mathematical performance at tertiary level. Many students in South Africa do not have the finances to pay for university fees in addition to difficulty in obtaining funding and challenges in accessing learning resources (Higher Education Learning and Teaching Association of Southern Africa, 2009; Bozalek, Garraway and McKenna, 2011). This argument led to the two research questions that enquired about the key problems experienced by the learner and how the intervention addresses these problems.

3.4.2 Mathematical capability

There is a need for the development of mathematical capabilities in learners using formal rules and axioms (Cirino *et al.*, 2016). The rules and axioms of mathematics promote abstraction on which mathematics builds. Arithmetic skills in children at primary school level become assets in future academic studies (Takane, Tshekane and Askew, 2017).

Figure 3.2 demonstrates a computer interface that assisted primary school learners in gaining mathematical capability through edutainment using arithmetic.

Figure 3.2: User interface for a single problem

As illustrated in Figure 3.2, the application of arithmetic rules and axioms is translated to students. In return, students use the computer interface to learn mathematics. The type of education that promotes mathematical capability should be active, enquiry-based learning to stimulate cognitive interest in learning mathematics (Baxen, Nsubuga and Johansson Botha, 2014; Cēdere *et al.*, 2015). For learners to acquire mathematical skills, government should promote equal and supported learning for all learners in the country. Educational policies based on equity, flexibility, creativity, teacher professionalism and trust are examples of system-wide excellence in student learning (Sahlberg, 2006).

Mathematical capabilities accounted for a country's ability to write affirmative action policies that promoted racial and ethnic diversity in the selection of medical students at medical schools since diversity enhances learning and cultural competencies. The contestation is that in classes where an educator teaches the context and a tutor helps the students with tutorials, misalignment prohibits epistemological transfer of mathematical capabilities due to work missed in transit (Grenier-Boley, 2014). Teachers miss opportunities to address gaps in students' mathematical capabilities because they have no link to the students with the tutor being in between. As such, the teacher deprives learners of opportunities to ask questions during lessons. Students do not engage with the material in class and they are compelled to wait until a tutor engages with them. A relationship is formed with the tutor and not with the subject teacher, who is the person who develops content, sets examinations and passes the learners. Students do not benefit in such arrangements since it creates a misalignment between what learners learn, what they should learn and what learners are tutored in.

Therefore, allowing students to pose their own questions for their own learning engages the students more and thus gives the teacher more understanding about the students' missing knowledge. The teachers' intent should be to increase the students' self-expansion, which may lead to self-knowledge and truly widened consciousness (Engeström, 2001; Engeström, 2015). An education system that trusts students to learn and to acquire knowledge empowers the students to become successful in their mathematics assessments, as seen in the TIMSS assessments of Finland for several consecutive years (Sahlberg, 2006).

A country's growth depends, inter alia, on increased gender equity and education equity. Gender equity and education equity should be supported through enacted policies that reflect the country's full support for increases in the country's human capital through education, resulting in increased economic activity (Sahlberg, 2006) In addition, gaining mathematical capabilities is reliant on a learner's language proficiency in Mathematics (Belfiore, Rudas, and Matrisciano, 2010; Binbasaran-Tuysuzoglu and Greene, 2014). However, knowing what works in enhancing students' mathematics capability depends on many variables like understanding the political and the institutional environment in which the treatment is set.

Figure 3.3 illustrates different variables to be considered when setting up a treatment towards enhancing the mathematics capability of students.

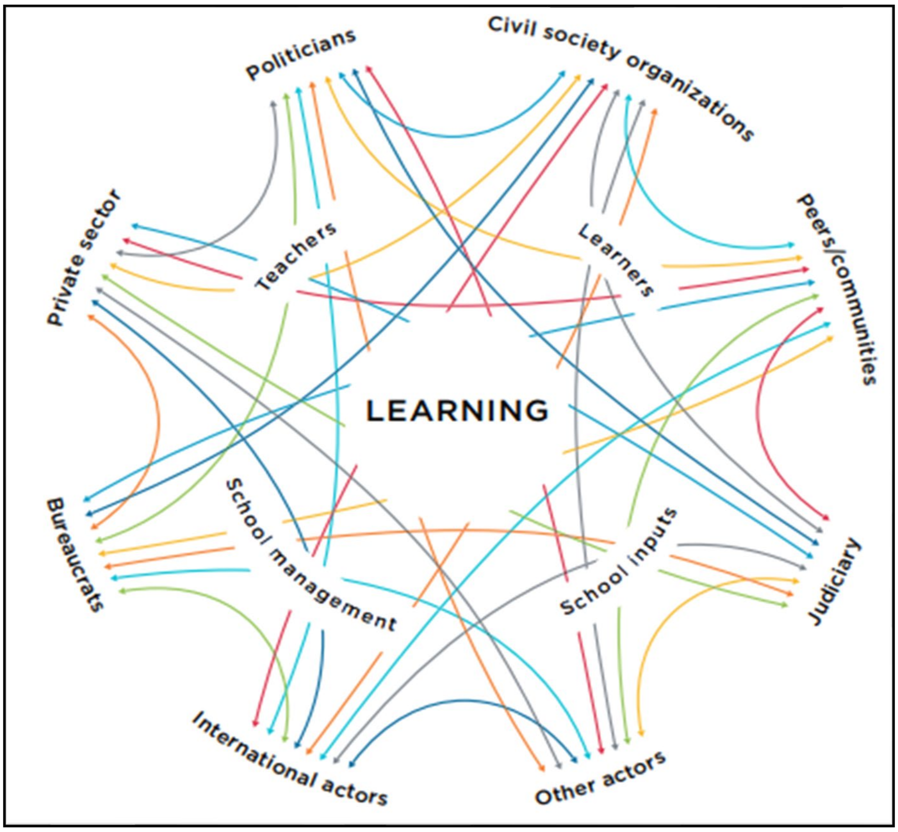


Figure 3.3: Learning stakeholders (Nordic Council of Ministers, 2018)

Figure 3.3 demonstrates that thus far, the mathematics capability enhancement interventions that are successful are those that have full support from all relevant stakeholders (Sahlberg, 2010). Language proficiency in Mathematics relates to a learners' ability to think mathematically in solving mathematical problems (Schoenfeld, 1992; Schoenfeld and Pearson, 2009). Learners can demonstrate their mathematical skills by conceptualising and synthesising mathematical skills and life skills to solve current and future real-life problems in their academic lives. This stimulates a learner's understanding of Mathematics (Ohlsson, 1992).

Figure 3.4 is an attempt at simulating how a learner's human brain links alpha and numeric variables during a problem-solving interaction. This process is called the multi-layer neural network (MLNN).

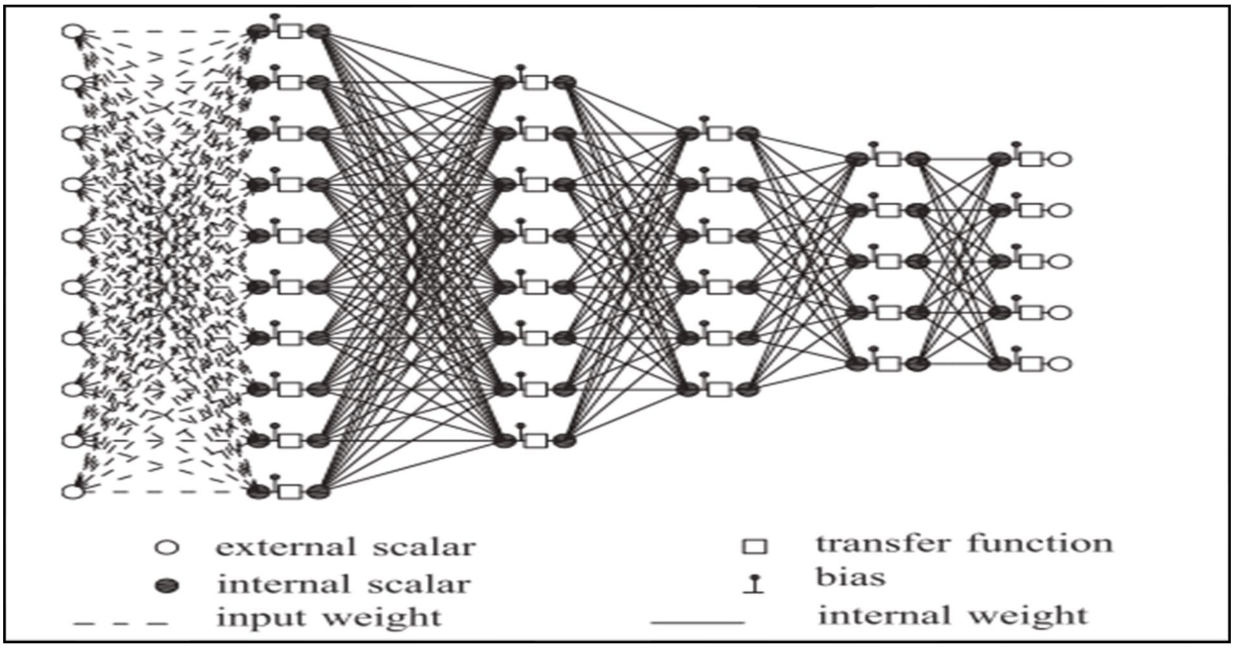
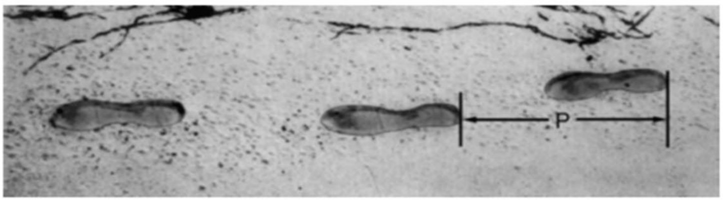


Figure 3.4: Architecture of an adopted multi-layer neural network (Belfiore, Rudas and Matrisciano, 2010)

Figure 3.4 illustrate a feed-forward MLNN to deal simultaneously with two different problems of summing integers and recognising literal characters. There is no specific algorithm used since none exists to date. Using the analogy of an artificial neural network (NN), Belfiore, Rudas and Matrisciano (2010) demonstrate how the human brain uses trained NNs to recognise human handwriting and numerical values since NNs can code information and thus solve mathematical problems. There are more variations for how simple and complex problems are solved this way. The point of this literature engagement is that learners' problem-solving capabilities are developed using a hybrid of mathematics and robotics. Ultimately, gaining mathematical capabilities means closing the mathematics learning gap created by the implementation of curriculum 2005 for Grade 10 to Grade 12 learners in South Africa approximately 15 years ago. Mathematical ability

Mathematical ability involves, inter alia, the ability to use cognitive skills to solve problems mathematically, to use visual-spatial memory, to conceptualise mathematical problems and to use reflective thinking and cognitive thinking towards problem-solving (Demirel, Derman and Karagerick, 2015; Wang, Guo and Jou, 2015; Cirino *et al.*, 2016). Mathematical knowledge is transferred using visual and spatial ability at different levels of the learning. The learner's cognitive ability determines the level at which the learner acquires mathematics epistemology but the visual-spatial concept still operates in the same way. For example, in Figure 3.5, a teacher used a real-life problem to help high school students learn the geometrical concepts of shape, speed, time and distance (rates) (Organisation for Economic Co-operation and Development, 2013). The sketch represented in Figure 3.5 illustrates geometric functioning in real-life.

WALKING



The picture shows the footprints of a man walking. The pacelength P is the distance between the rear of two consecutive footprints.

For men, the formula $\frac{n}{P} = 140$ gives an approximate relationship between n and P where

n = number of steps per minute, and

P = pacelength in metres.

Question 1:

If the formula applies to Heiko's walking and Heiko takes 70 steps per minute, what is Heiko's pacelength? Show your work.

Question 2:

Bernard knows his pacelength is 0.80 metres. The formula applies to Bernard's walking.
Calculate Bernard's walking speed in metres per minute and in kilometres per hour. Show your working out.

Figure 3.5: An illustrative item – Walking (Organisation for Economic Co-operation and Development, 2013)

Students are expected to use mathematical formulae to solve problems and thus need to have the mathematical cognitive abilities to link the problem to a formula. A Mathematics teacher in a primary school used edutainment to motivate children to learn mathematics.

Some authors stated that students achieved mathematical abilities better when they felt enthusiastic. An enthusiastic feeling was attributed to a teacher who structured the course such that students felt that they had exciting academic experiences. The critical aspect of literacy in mathematics is focused on the importance of students developing a strong understanding of the concepts of pure Mathematics and the benefits of being engaged in explorations in the abstract world of mathematics (Organisation for Economic Co-operation and Development, 2013). Figure 3.6 demonstrates the use of edutainment to stimulate enthusiastic feelings in learners while they acquire mathematical capabilities.

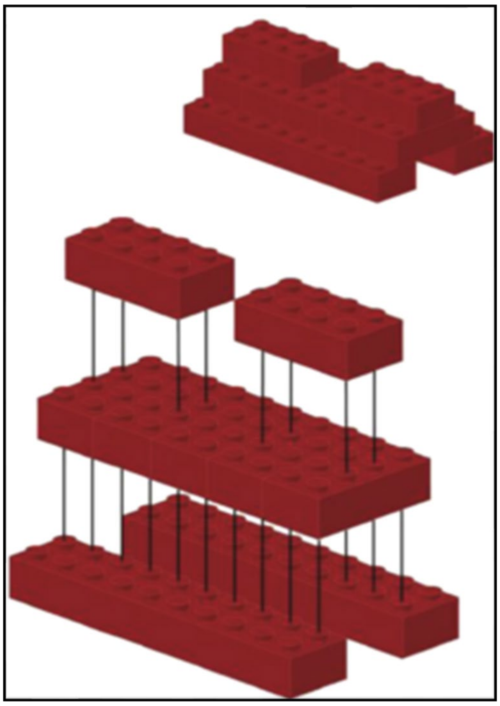


Figure 3.6: Exploded isometric model instructions (Richardson, Jones and Torrance, 2004)

Figure 3.6 represents an exercise in which nine different shaped and different sized Lego blocks were presented to learners. The teacher instructed the learners to use the Lego blocks to construct shapes. This method encouraged interaction between the teacher and the learners during the capacity-building of mathematical capabilities in the learners (Richardson, Jones, G. and Torrance, 2004). Thus, students' anxiety about learning Mathematics and acquiring numeracy skills were diverted (Ramirez *et al.*, 2016).

Mathematical abilities are constructed when a teacher gives students feedback about their weaknesses and strengths in mathematics. PISA assesses the extent to which children near the end of compulsory education have acquired the knowledge and skills and TALIS is an international survey that examines teaching and learning environments in schools of participating countries around the world (Organisation for Economic Co-operation and Development, 2015). However, the provision of PISA and TALIS does not suffice the mathematical needs of learners in Nordic countries (Ludvigen *et al.*, 2016).

3.4.3 Knowledge acquisition

Knowledge is acquired by integrating a guided instructional approach and computational skills in order to transfer mathematical capability to learners. Information technology products like automated machines could be used to cultivate conceptual understanding, to augment critical thinking and to promote learning in the domains of Mathematics and Science (Sheahan, While and Bloomfield, 2015; Atmatzidou and Demetriadis, 2015; Ting, 2015; Wang, Guo and Jou, 2015). Knowledge acquisition is not a one-step process; many strategies are required to maximise the efficacy of a mathematical capability intervention. Therefore, a Mathematics teacher should have the ability to prepare all-inclusive Mathematics lessons. Mathematics lessons are required for epistemological transfer by the teachers and the effective acquisition of mathematical capabilities by learners (Reddy, Van Der Berg, Van Rensburg and Taylor, 2012).

In contrast, government policies can have a positive or a negative impact on the acquisition of mathematical knowledge (Kezar, 2013). Therefore, public school examinations for learners that are used as an avenue to access generic skills fail to allow students to acquire mathematical capabilities because the assessments are composed for the wrong reasons (Leung, Leung and Zuo, 2014). For example, they used examinations to access generic skills instead of realising that knowledge acquisition comes from the diversity of assessment methods used to assess learners. De Jager, (2012) states that acquiring knowledge in mathematics is a long process that requires tenacity and resilience from all parties involved. To gain mathematical knowledge, one needs executive cognition

(Valiente-Barroso and García-García, 2012). Executive cognition is described as a function that one develops in adolescence (Paus, 2005). Executive cognition is considered a fundamental mathematical learning instrument that formulates the abstract reasoning that is needed to become successful in studying and remaining successful in mathematical studies (Blair, Knipe and Gamson, 2008; Vandenbroucke, Verschueren and Baeyens, 2017).

When executive function is linked with visual spatial learning, it creates a numerical skills base for young pupils. Therefore, mathematical knowledge that is acquired in the formative years is used to scaffold knowledge attained in later years and this is fundamental to the successful acquisition of mathematical skills (Dabbagh and Kitsantas, 2012; Kwan and Wong, 2015). Hence, in the enhancement of Mathematics capabilities intervention administered to the research participants in the HCINCT programme, the first three weeks of the QT programme focused on capacitating the research participants with the mathematical skills taught at Grade 6 level in primary schools in South Africa. This was done to close the mathematical skills gap that was apparent in the research participants upon entry to the UoT in February 2015.

Figure 3.7 displays a process in which learning takes place when the model-based inquiry model of learning mathematics is used.

		
Teacher scaffolding: Teacher-supported prompting, dialogue and plenaries, making links with prior learning. (Reiser, 2004; Wood et al., 1976)	**Small group discussion:** Social construction of knowledge. (Brown et al., 1989)	**Model-based inquiry:** Understanding and applying the model(s), which needs to be presented explicitly. (Windschitl et al., 2008)

Figure 3.7: A process of model-based enquiry (Nuffield Foundation, 2013)

In the first picture of Figure 3.7, a teacher scaffolds the mathematical capabilities of a learner at primary school by promoting dialogue and lessons to connect and to synchronise prior mathematics learning with existing and newly acquired mathematics (Wood, Bruner and Ross, 1976; Reiser, 2004; Wood, Pectoz and Reid, 2012). The centre picture of Figure 3.7 displays how students acquire mathematical skills in middle or high school. The picture demonstrates the ways in which learners study in small groups by engaging in class tutorials and mathematics symposiums to discuss mathematical concepts. In this instance, mathematical capabilities are acquired through the social construction of knowledge.

The teacher facilitates the epistemological transfer of mathematics to learners. The students share sharing mathematical knowledge with other students in the group (Lalli, Mace, Browder and Brown, 1989). Scientific education teachers should use realistic scenarios in scientific education to enable their students to acquire scientific knowledge and to develop their skills. This increases the students' investigative and innovative skills (Windschitl and Thompson, 2006; Windschitl, Thompson and Braaten, 2008). The last picture in Figure 3.7 demonstrates how learners acquire mathematical capabilities at university or college and how they conceptualise the learning through the application of the models/concepts (Nuffield Foundation, 2013). When mathematical knowledge is acquired at all levels of the learner's education through scaffolding, new mathematical skills are gained. Therefore, linking the conceptual framework of the current intervention, Iterative ADDIE to the research question that asks when are the opportune successes of the intervention best optimised and the failures best mitigated (Cronje, 2013) answers the research question and provides the solution to the research problems, thus contributing to knowledge.

3.4.4 Mathematics anxiety

Students' anxiety towards Mathematics prevents students from acquiring mathematical capabilities (Karasel, Ayda and Tezer, 2010; Ramirez *et al.*, 2016). Students should be encouraged to learn by creating a safe learning environment in which their attitudes towards mathematics are addressed in a constructive and positive way because negative attitudes and anxiety do not contribute to successful performance in Mathematics (Rohlwink, 2015). Students should divert their anxiety towards Mathematics by converging reflective thinking skills (Demirel, Derman and Karagerick, 2015). It has been demonstrated that students' anxiety towards Mathematics causes students to make errors when solving calculus-related problems (Locklear, 2012).

On the one hand, teachers who provide feedback to students regarding students' mathematical capabilities calm the students' anxiety towards learning Mathematics (Kim, M. K., Kim, S. M., Khera and Getma, 2014; Carvalho, Conboy, Santos, Fonseca, Tavares, Martins, Salema, Fiuza and Gama, 2015). On the other hand, teachers of Mathematics and Science in high achieving schools in Swaziland become anxious when major assessment results are due for publication by the Swaziland Department of Education

(Putsoa *et al.*, 2003; Mamba and Putsoa, 2013). Therefore, teachers' apprehension in regard to results may show dedication and competitiveness on the part of the teachers, contradicting all previous views. Thus, it is not anxiety that one should be concerned about but rather the attitude that manifests itself at different levels that may distract the learner from learning Mathematics (Savelsbergh *et al.*, 2016).

3.4.5 Alignment

The university curriculum is constructed such that its outputs directly develop a graduate's capability for dealing with situations that predetermine the student's professional, social and personal life (Baillie, Bowden and Meyer, 2013). There is an urgent and worldwide need for reform in education systems whereby the systems that are aligned to the subject of Mathematics allow for design of the students' mathematical skills and also capacitate the proficiency of the students' mathematical capabilities so that the mathematical skills gained by students at the end of their education allow them to think critically and creatively (Leung, Leung and Zuo, 2014).

On the contrary, the use of inquiry-based learning and modelling in science and mathematics education reinforces the principles of computational experimentation (Psycharis, 2016). Computational experimentation models are used as the fundamental instructional units of Inquiry-Based Science Education (IBSE) and Science, Technology, Engineering and Mathematics (STEM) education (Psycharis, 2016). Psycharis (2016) explains further that in IBSE and STEM education, the model of transferring knowledge to students is conducted in a way that takes the place of the classical experimental set up in which simulation replaces the experiment. Therefore, successful enhancement of IBSE and STEM education models involves interconnectedness with the students in a process in which the students themselves take ownership of the model by claiming it and using it.

Thus, higher education institutions should build an educational framework that provides their students with opportunities to contribute to economic development by drawing on evolutionary economics and utilising the national innovation systems approach. The type of education needed today is based on collaborative efforts. Collaborative efforts include personnel who are directly linked to the learners and people who are linked to the learners via others such as IT-support personnel (Intanam and Wongwanich, 2014). Thus, a professional learning community within a school environment comprising people with the varied yet critical skills needed for learners to learn mathematics effectively should be established. Student learning centred on students' educational needs is preferable and more effective for acquiring mathematical capabilities than providing student learning centred on what the teacher thinks the students need to learn (Judi and Sahari, 2013). Students who are motivated by their teachers to seek and to gain knowledge learn better (Chen, 2010), while specialised teaching methods used to transfer and manage knowledge are most effective (Pappanastos, Hall and Honan., 2002; Miller, Roberts, Hale and Lanie, 2012).

3.4.6 Mathematics self-efficacy

Students needed academic self-efficacy (Applewhite, 2015). According to Applewhite (2015) academic self-efficacy is significant in a student's successful transition process from high school education to tertiary education. The opposing notion to academic self-efficacy states that students require not only academic self-efficacy but also mathematics self-efficacy to augment their mathematical capabilities (Greene and Azevedo, 2010) In support, the notion of mathematics self-efficacy entails learners' self-regulation driven by their motivation for academic acquisition (Locklear, 2012; Binbasaran-Tuysuzoglu and Greene, 2014; Ben-Eliyahu and Linnenbrink-Garcia, 2015).

Future mathematics interventions should include studies that enhance students' self-belief to encourage them to take charge of their mathematics education. Perceived self-efficacy and personal goals enhance motivation and performance attainment (Bandura, 2006). The question addressed in this section of the literature review was why some aspects of the intervention were successful and others were not. The inability of the literature review to answer this research question led to an identified gap in the literature.

3.4.7 Attitude

Attitudes are inclinations and predispositions that guide an individual's behaviour and persuade the individual to act; attitudes are evaluated as either positive or negative (Rubinstein, 1986). Attitudes develop and change with time. Factors affecting students' attitudes towards learning mathematics include mathematics achievement scores, anxiety towards the subject of Mathematics, self-efficacy and self-concept, intrinsic motivation and high school Mathematics experiences (Köğce, Yildiz, Aydin and Altındağ, 2009). Teachers' approaches in effective epistemological transfer of mathematical skills should motivate learners towards a positive attitude to learning (Intanam and Wongwanich, 2014) and through their learning materials, should create a positive paradigm shift.

Therefore, teachers' strategies for transferring knowledge to students should come from a community of professionals working together to form this type of learning experience for learners (Wang, Guo and Jou, 2015). However, teaching and delivery of mathematical skills lack a composite that measures students' attitudes towards the acquisition of mathematical skills (Savelsbergh *et al.*, 2016). Before constructive learning can take place, there should be a belief system ingrained in the learners with regard to their achievements (Canfield, Ghafoor and Abdelrahman, 2012).

Hence, achievement in mathematics is based on students' self-beliefs and cognitive strategies that students implement to achieve their academic goals (HELTASA, 2009). Opposing ideas argue that a country's government policy and a well-structured curriculum prepare the ground for students to have positive attitudes towards acquiring mathematical skills. Students' critical mathematical abilities affect and motivate their attitudes towards learning and acquiring mathematical capabilities (Kwan and Wong, 2015).

Kwan and Wong (2015) continue that learners should improve poor performance by securing a positive attitude, eliminating anxiety and using prior mathematical ability and self-efficacy to acquire aligned posterior mathematical capabilities. However, Kwan and Wong (2015) do not consider how the intervention addresses the problems. This literature-reviewing process assisted the researcher in constructing sub-questions and formulating the main research question for this investigation. The constructs could be grouped into two categories, scaffolding and cognition.

3.5 GAPS IN THE LITERATURE REVIEW

Most authors who wrote about the mathematical challenges of university students approached the problem from a socio-capabilities perspective. However, questions concerning what are core in enhancing the mathematical skills of university students in IT disciplines were left unanswered. There was no mention of the fact that first-year IT students need enhancement of their mathematical capabilities or why their mathematical capabilities need enhancement. Moreover, there is no existing theory known to the author of this thesis that addresses the topic under study in a way that answers the problem statement and the research questions of this investigation. The authors mentioned in Table 3.2 describe encountered challenges that pertain to the topic of this research and indicate how the problems were addressed.

However, a gap was identified in the literature because this earlier work addressed problems at educational levels prior to university studies. Despite the many views, claims and assertions made by the writers in the literature review under the subject of enhancing mathematical capabilities of first-year IT students at a UoT, no literature was found that addressed the topic under investigation. Moreover, the magnitude of the gap was unknown. Students' self-pride and dignity was foremost in determining learning materials and assessments that would make a meaningful contribution to the students' acquisition of mathematical knowledge without reducing the students' self-esteem.

Although the literature reviewed showed that there was commendable work being conducted, a gap for the conduct of this investigation existed since none of the work presented addressed the research question. The research question was to determine the circumstances in which the students' results improved through a particular mathematics intervention. The literature reviewed presented ideas on how the mathematical abilities of research participants were addressed in the early developmental stages. However, the practicalities of the suggested interventions did not suffice the mathematical ability needs of first-year IT students at university. Therefore, a need for the investigation was created by this identified gap in the literature. The eight constructs derived from the combined literature reviews were summarised into two categories, namely (a) scaffolding; and (b) cognition. The following section is a brief discussion on each category.

3.6 SCAFFOLDING CATEGORY

Prior mathematical knowledge is critical to the scaffolding of new mathematical concepts (Reiser, 2004; Anghileri, 2006; Opfer, Thompson and Kim, 2016; Brower, Woods, Jones, Park and Hu 2017). Bad or good mathematics experiences in early education could accumulate as cognitive bias towards learning mathematics. There are disadvantages for relying on long-term memory alone for gaining mathematical cognition. One needs to use a variety of tools to help students acquire mathematical capability. For instance, one establishes semantic relations between the influence of real-world objects and how students set up the mathematical equations used to solve word problems (Bassok, DeWolf, Holyoak and Keith, 2015 . This is illustrated via Figure 3.8.

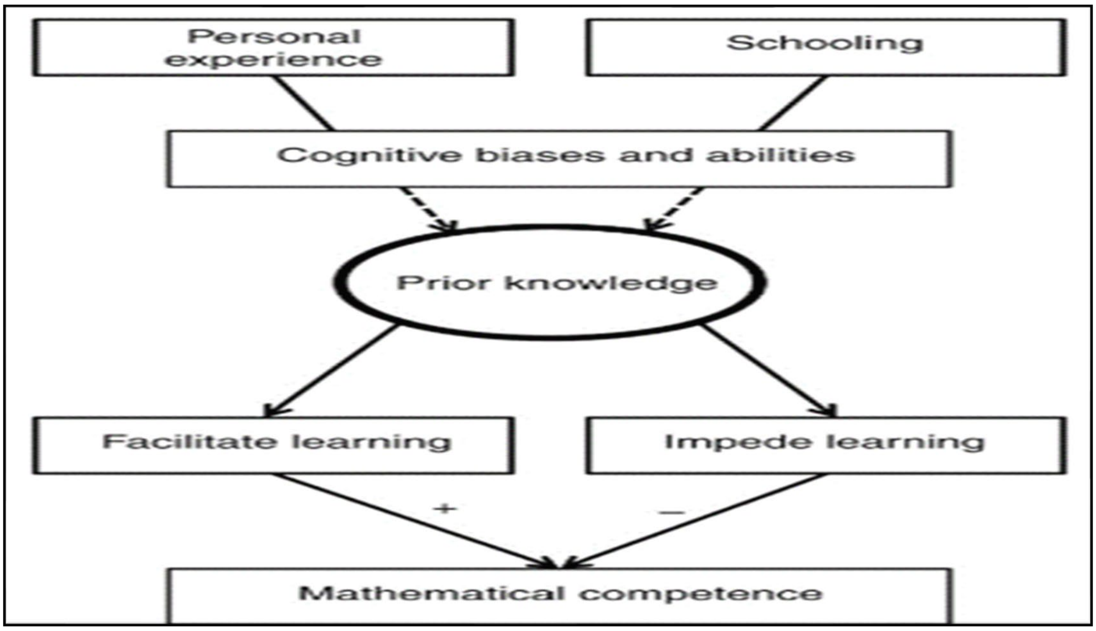


Figure 3.8: Mathematical cognition and learning (Geary, Berch, Ochsendorf and Koepke, 2017)

Scaffolding mathematical knowledge may explain the changing patterns in students' success in acquiring mathematical knowledge (Vygotsky, 1978; Reiser, 2004; Anghileri, 2006). Scaffolding requires the development of critical thinking abilities in students (Blum, Ferri and Maaß, 2012; Holmes, Wieman and Bonn., 2015; Kwan and Wong, 2015). Principles laid down in (Vygotsky, 1978). Vygotsky's (1978) developmental model of the Zone of Proximal Development (ZPD) were utilised to ascertain students' mathematical capabilities and mathematical abilities on entry into the HCINCT programme. The students reflected poor performance due to inadequate foundational arithmetic/practical mathematical skills (Makgato, 2007; Norton, 2008; Organisation for Economic Co-operation and Development, 2013).

3.7 COGNITION CATEGORY

Students' personal experiences with arithmetic education in their early years accounts for the attitudes and feelings that they develop and later exhibit at university. Portraying positive emotions towards learning mathematics is pivotal to enhancing a student's mathematical abilities (Sangcap, 2010; Mohamed and Waheed, 2011). However, there are time constraints at university and developmental courses are usually attached to other major courses. In addition, college/university students have to cope with many new aspects (Cockerham, 2011). This occurred with the intervention programme of this study, although QT was one of the major courses in the HCINCT programme. According to Karasel, Ayda and Tezer (2010), Rohlwink (2015) and Ramirez *et al.* (2016), students' anxiety towards acquiring mathematical knowledge prevents the student from acquiring the required mathematical skills.

The critical factor here is that students should be able to prevent prior knowledge from influencing mathematical abstract problem-solving. This leads to the question: What are the attributes that one needs to be cognisant of when designing an intervention/s to enhance students' mathematical capabilities? The answer to this question is presented in Figure 3.8. Students' personal experiences in mathematics are based on the students' experiences both out of and within school environments and these experiences shape the way that learners perceive mathematics. Cognitive science illustrates that prior knowledge can facilitate or impede learning in students because students' prior knowledge is defined by out-of-school and within school experiences that include learning materials such as the textbooks that are given to the students.

Students' socio-economic backgrounds can generate inequalities in the mathematical skill levels of learners, for example, the type of school to which learners were exposed in their early mathematical development (Chen and Yu, 2016). Therefore, an intervention programme must be aligned to the requirements of the course that the intervention programme was designed to assist (Biggs, 1996; Calitz, 2010; Leung, Leung and Zuo, 2014). While students and their teachers need to use structural alignment that leads to interpretive reasoning about arithmetic word problems (Basson, Chase and Martin, 1998; Bassok, Samuel and Oskarsson, 2008), the teacher has to be the facilitator of learning and this should be done in a way that does not impede learning. If this is done well, the outcome is the building of mathematical competence in learners by their lecturer/s.

3.8 ROLE OF THEORY IN LITERATURE REVIEW

The purpose of theories is to help a researcher find solutions to the research problem (Bergen and While, 2000; Fenwick and Edwards, 2011). Thus, theories help a researcher to find answers to the research questions that drive the research (Maton, 2013). Each research project should be associated with an explicit research philosophy/theory (Welman, Kruger and Mitchell, 2005). The study was conducted to comprehend the building blocks of the theoretical archetype. The research process is seen as a holistic process that unites all the different aspects of the research process. Figure 3.9 demonstrates the role played by the experiential learning theory (ELT) during the literature reviewing process.

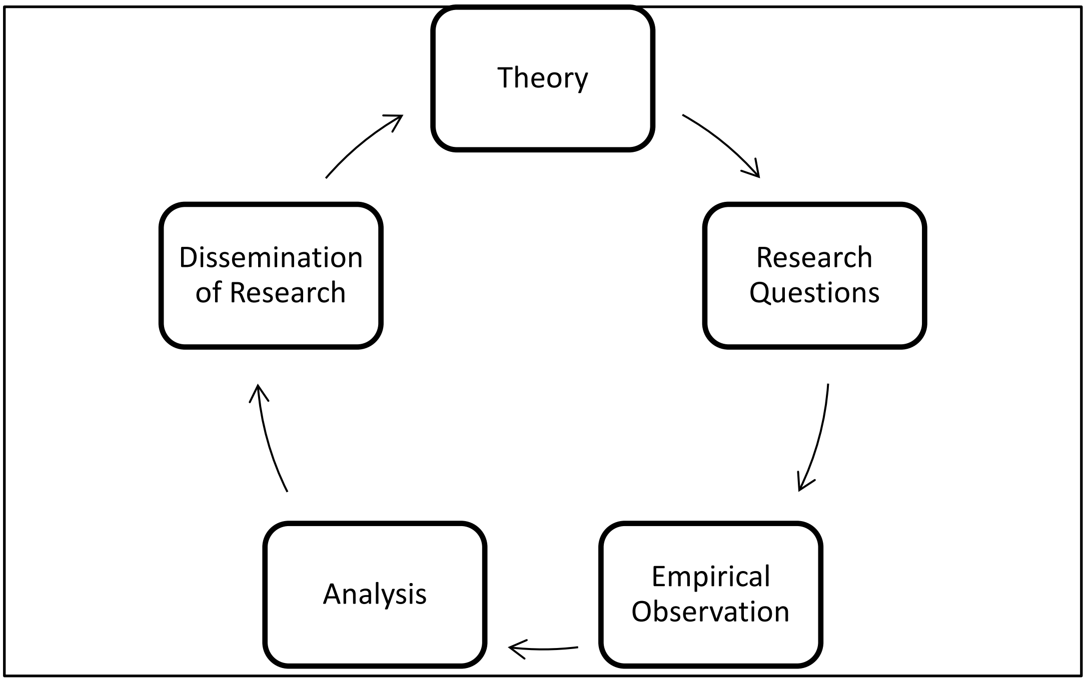


Figure 3.9: The research cycle (Da Silver Duarte, 2016)

Figure 3.9 shows how all the sections of the research cycle interconnect, integrating the literature reviewing process with other elements in the cycle. Synthesis occurs by connecting all the sections back to the theory. Each section has its own role in the research process but together, the investigation process gains strength, scope and synergy. In the build-up to writing the literature review, a search was conducted for an appropriate video that explained vividly how the fusion between different elements of the research cycle connected back to the literature review using theory as a guide. A lesson learnt from the video was that theory guides the literature reviewing process of an investigation and the findings of the investigation link back to the theory and the literature reviewed (Fenwick and Edwards, 2011).

The literature reviewed was used in Chapter 4 in which the findings are linked back to the literature that supports or refutes them in support of the tentative answer to the research question. The link directs one to the video that was found to be suitable for addressing the needs of this investigation https://www.youtube.com/watch?v=AiZGctlLvb4. The following section is an explanation of how each aspect of the research cycle was utilised in this investigation.

3.8.1 Theory

Theory includes literature reviewed, research results of others, research questions, aims of the research and current trends. Theory guided the selection of the literature reviewed and helped to keep the goals of the literature review consistent with the research questions. During the literature reviewing process, theory guided the technique for searching for influential, current and past trends in the body of knowledge. Recommendations and current trends found in theories were used in the search for journal articles and doctoral dissertations in pursuit of answers to the research questions and solutions to this study's problem statement. Hypotheses were tested in search for answers to the quantitative research questions. Eleven purposefully selected students were interviewed to find answers to the qualitative research questions.

3.8.2 Research questions

The research questions are an elaboration of the research plan, using research methods to find answers to the research question and a solution to the research problem (Babbie, 2013). The research questions are derived from the literature review process. In this study, the research questions allowed for the development of a conceptual framework and the literature reviewing process showed the gaps that existed and that justified this study. Initially, there were five research questions, but the research process allowed for streamlining of the research questions until one main research question and two sub-questions were found to be suitable for directing the investigation.

3.8.3 Empirical observation

This process in the research cycle involved data collection. Observation of the mathematical capabilities of first-year IT students before they entered the HCINCT foundation programme of QT 2015 assisted in the development of a series of interventions that were later administered to the students to enhance their mathematical skills. Five sets of assessments were conducted, specifically searching for answers to the research questions. The students' assessment scores did not form part of the QT syllabus. However, the assessment scores formed part of the empirical data that were used to analyze the efficacy of the MCI administered through QT class tutorials registered in the HCINCT programme of 2015.

3.8.4 Analysis

Data analyzes were structured systematically to form a coherent data analysis process that enabled identification of the findings of the research. The analysis process was a quality control aspect of the investigation whereby the findings were used to check for synthesis back to issues that occurred in the real world. Lessons that were learnt and the outcome of the research told a story that was believable, realistic, reliable and valid. The analysis stage involves problem-solving and resolving process flow (Van den Akker *et al.*, 2013).

3.8.5 Dissemination

Story-telling was used to create awareness and to inform other researchers about this investigation. The framework and strategy that guided the dissemination and underpinned this investigation were crucial to the success of the study (Saywell and Cotton, 1999). Propagation and communication of research is pivotal in creating awareness of one's research outputs (European Union, 2014; Marin-Gonzalez, Malmusi, Camprubi and Borrell, 2016). Therefore, dissemination of the proposed research outputs was conducted to learn about the concepts that were involved in the research arena through which this investigation was conducted.

Investigation engagements were propagated to promote the topic of this study and to create an academic debate in order to gain views from academia about the topic (Stone, Corinne, Pearson, Morgan and Jensen, 2006). Furthermore, the research was broadcast to the IT Department and later to the Faculty of Informatics and Design to receive constructive feedback from experienced researchers. Two research proposal defences were conducted successfully. One research proposal defence took place within the IT Department and feedback gained was used to modify the research proposal document. The second research proposal defence took place in the Faculty of Informatics and Design. Constructive feedback was obtained and incorporated into the research proposal that formed the basis of this document.

3.9 CONCLUSION OF LITERATURE REVIEW

The literature review showed evidence of a gap in the enhancement of operational mathematical capabilities for first-year IT students at the UoT. The literature reviewed also revealed that students entering university for the first time were mathematically underprepared to pursue studies that required a solid foundation in mathematics and this was not solely relevant to a South African educational context but was a global problem (Hemmi, 2006; Brandell, Hemmi and Thunberg, 2008). According to the literature, this scourge has created a gap in the mathematical capabilities of learners from the elementary build of mathematical skills at primary school level through to high school level (Gustafsson, 2005; Fleisch, 2008). The literature also showed that universities throughout the world are implementing mathematics intervention programmes aimed at enhancing their students' mathematical capabilities (Gedrovics and Cēdere, 2014).

During the investigation, it was discovered that there were combinations of enhancement interventions for mathematical capabilities that were administered across various genres in education, including engineering, computer sciences and natural sciences (Bozalek, Garraway and McKenna, 2011). At the end of the literature review process, it was determined that there was still a need for this investigation because most augmentation interventions for mathematics that existed at the time of this study had been conducted in the sphere of natural sciences. It was also deduced from the literature reviewed that there were a limited number of interventions directed at enhancing the mathematical capabilities of first-year IT or computer science students at a UoT (Ford, 2015).

4 CHAPTER 4: RESEARCH DESIGN AND METHODS

This investigation aimed to fill a gap in the educational genre through which the research was conducted. The literature reviewed in Chapter 3 showed that most mathematics interventions are conducted at primary school level (Fleisch, 2008; Spaull, 2013; Takane, Tshekane and Askew, 2017) while a small number of interventions are administered at high school level (Lynch and Kim, 2016). However, the review documented that globally, only a few mathematics interventions have been conducted at university level (Worthley, 2013; Ford, 2015) and this created the gap that this study tried to address. In this chapter, the research paradigm, methodology, research methods and the ethics guidelines that were followed during the conduct of the investigation are presented.

The sequence of reporting is demonstrated in Figure 4.1.

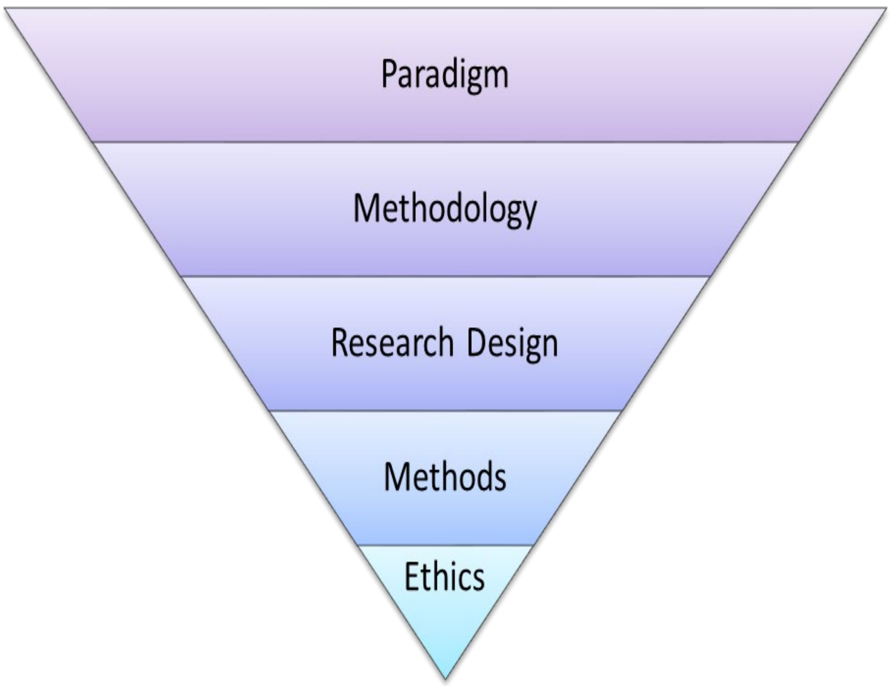


Figure 4.1: Research Methodology

Figure 4.1 illustrates the research methodology structure. This section begins by discussing the pragmatism philosophy that directed the investigation in finding answers and thus solving the research problem.

4.1 RESEARCH PARADIGM

Pragmatism was chosen as the philosophical rationale that guided the study. According to Morgan (2007), pragmatism supports researchers in choosing between different models of inquiry. Morgan (2007) states that the research question determines the methods used to answer it. The criterion for choosing a philosophical paradigm for this study was driven by the research questions, the methods used, the research design, the ontology and the mathematic epistemology attributes of the study (Albouy, 2004; Wiersma and Jurs, 2009; Kotrlik, Williams and Jabor, 2011). The research questions, the research problem, the data type, the instruments of data collection and data analysis informs the philosophical paradigm.

Figure 4.2 demonstrates the research paradigm, the ontology, the epistemology and the methodology that guided the construction of this investigation.

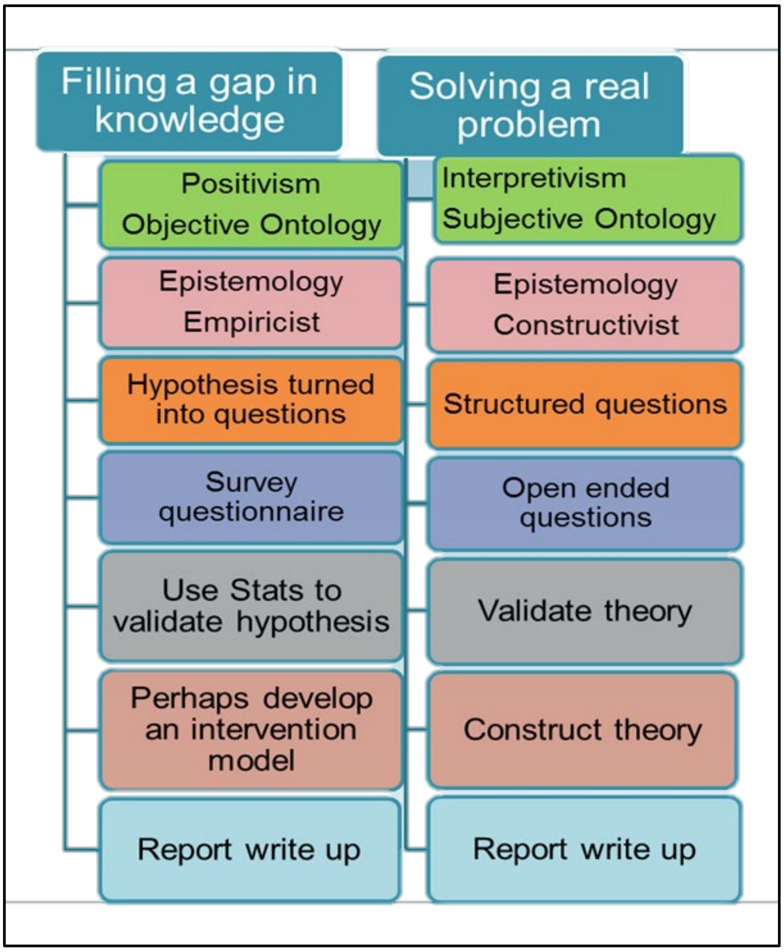


Figure 4.2: The research processes

The integration of the research methods demonstrated in Figure 4.2 manages the epistemic fallacy that occurs through being directly involved as a researcher in an investigation (Colliers, 1994; Archer, Bhaskar, Collier, Lawson and Norrie, 1998; Bhaskar, 2008; Archer and Maccarini, 2013) . The overarching objectives of this research were to enhance students' mathematical skills upon entry into the HCINCT programme so that they possess numeracy skills upon which their IT programming skills could be scaffolded. An interpretivist approach was used to understand the real problem of having most 18-year-old students enter their university studies equipped with the mathematical skills of an 11-year-old primary school pupil. The study was conducted so that the students could acquire mathematical capabilities and progress towards either attaining a national diploma in IT the year after their studies or acquiring their exit certification on completion (Alexander, 2013; Nzimande, 2016). Figure 4.3 demonstrates the questions that guided each critical research component.

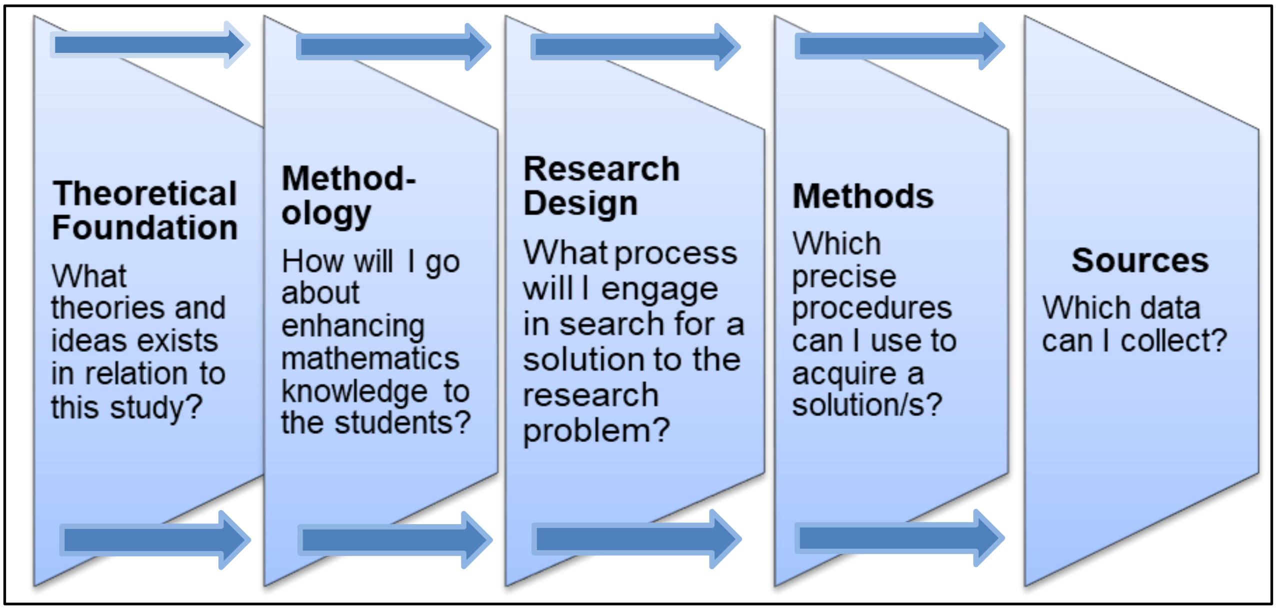


Figure 4.3: Interrelationship between the elements of the research

Figure 4.3 shows critical elements of the research. A discussion of each block and its characteristics in relation to the needs and purposes of the investigation follows. The ELT provided a theoretical foundation (Kolb, 2015). A hierarchical research methodology that synchronised all the elements of this research was needed (Babbie and Mouton, 2001; Kothari, 2004; Kothari, 2009; Babbie, 2013). This aspect was important to develop the want in students to acquire quantitative skills upon which their IT programming skills could scaffold. Students' intelligibility was reviewed, their intuitive knowledge was assessed and their understanding and their level of knowledge in mathematics were determined using the ELT framework. The ELT framework was used to implement teaching methods because theories are tools that are applied to solve problems (Kuhn, 1970; Lakatos, 1970). This notion is supported by (Brown, 1977) who attests that theories are viewed as the truth uncovered through rigorous experimentation, a perspective such as logical positivism and logical empiricism. The ELT model was also chosen for its focus on learning through experimentation and adaptation to the learners' and the teacher's social environment (Dewey, 1897; Dewey, 1904). There are three traditions of experiential learning (Kurt Lewin, John Dewey and Jean Piaget) upon which Kolb (2015) admits to having built the ELT theory of experiential learning.

Kolb (2015) defined experiential learning as a spiral of learning in which students learn from past occurrences, reflect on their past learning experiences and use these past learning experiences to acquire new knowledge. Therefore, the behaviour of this investigation relied on the implicit sociology formed by a concern to understand the world according to the students together with the students' mathematical capabilities observed in the study. By using mixed methods, comprehension of the social nature of the world was allowed in a subjective manner (Burrell and Morgan, 1979).

The investigation was able to operate under an exploratory and a functionalist perspective because the study had an element of exploration generated through the use of a series of mathematics interventions. This was made possible by blending the experiential learning model (Kolb, 2015) and the instructional design that was chosen for the study (Dick, Carey and Carey, 2014). In contemporary mathematics education research, the assumption is that theoretical constructs such as discourses, positioning and power dynamics are less inter-related (Prediger, Bikner-Ahsbahas and Arzarello, 2008; Skog, 2012; 2012;Skog, 2014).

4.2 THE MATHEMATICS CAPABILITY INTERVENTION

The Mathematics Capability Intervention module is situated within a Higher Certificate in Communication Technology program.

Figure 4.4 contextualizes its relationship with academic entities. Furthermore it informs the research design and method adopted in the study.

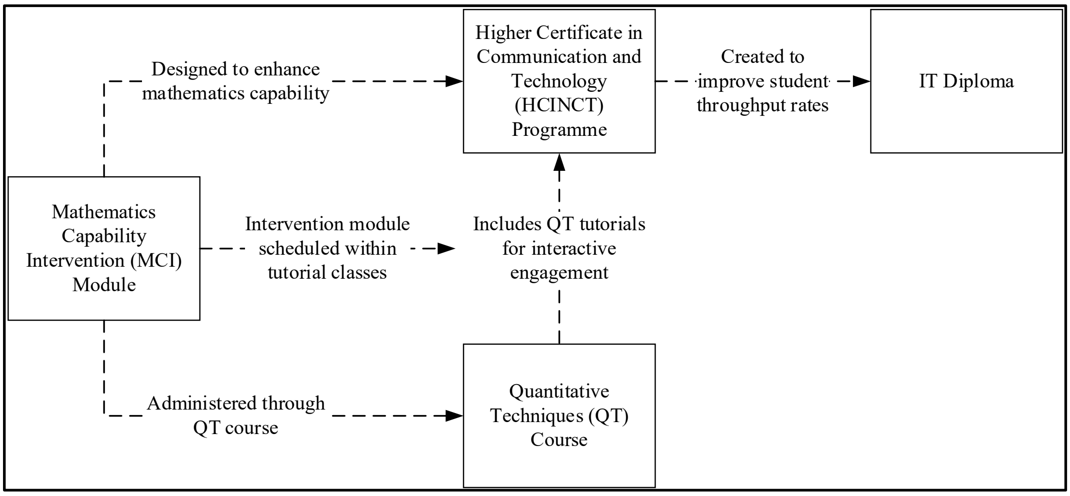


Figure 4.4: Contextual elements of the study include a module, a programme, a course and a diploma

Four objectives guided the Methodology strategy: (1) to explain the research plan; (2) to show the primary and secondary data sources used to collect data; (3) to demonstrate through sources in literature that the mixed methods instruments used to collect data for the study are reliable and trustworthy (Merriam, 2009); and (4) to show that the findings of this study can be compared with existing studies. A mixed methods sequential explanatory design approach was used for data collection, data analysis and data presentation to develop the scope and to advance the probing power of the investigation (Sandelowski, 2000;Tashakkori and Teddlie, 2003; Leech and Onwuegbuzie, 2009; Patton, 2014; Nastasi and Hitchcock, 2016).

The students were allowed to use cooperative learning to engage themselves with their newly acquired mathematical skills (Wang, 2014). Students that criticize and validate achieved mathematical models for the students own decision-making process resulted from interdisciplinary or extra-mathematical considerations. Mathematics theories, manipulators and apparatus were researched and implemented where their use was found appropriate to enhance the students' mathematical skills (Gningue, 2000; Gningue, Menil and Fuchs, 2014; Cope, 2015; Moeller, Fischer, Nuerk and Cress, 2015). During the QT class tutorials, the students engaged in small groups comprising two to three people. In these groups, the students' worked through mathematics problems, discussed their solutions and related their solutions to real-world problems. The gamification aspect of teaching mathematics was designed to keep the students engaged, interested and cognitively challenged while obtaining mathematical capability through playing the game/s (Al-Washmi, Hopkins and Blanchfield, 2013; Al-Washmi, Baines,Organ, Hopkins and Blanchfield, 2014). Edutainment and gamification were used to combine a non-fun concept such as education with the fun aspect of gaming to learn challenging mathematics concepts such as the theory in regard to probability theory and the logic theories (Connolly and Busch, 2014).

Edutainment has many descriptions; this study adopts the description that illustrates the concept as one that is both educational and entertaining (Walldén and Soronen, 2004; Rapeepisarn, Fung and Depickere, 2006). Edutainment in this investigation was achieved by combining media and education in the mathematics content. The use of gamification to acquire mathematical capability was intended to implement technological innovation into mathematics education (Marinelli and Pausch, 2004; Morgan and Kennewell, 2005; Buckingham and Scanlon, 2005). The investigation operated under an exploratory and functionalist perspective because the study had an element of exploration that was examined using a series of mathematics interventions. This was made possible by blending the experiential learning model (Kolb, 2015) and the iterative ADDIE conceptual framework (Branson, 1978; Berkowitz and O'Neil, 1979; Molenda, 2003; Dick, Carey, and Carey, 2001; Dick, Carey, and Carey, 2014).

In contemporary mathematics education research, the assumption is that theoretical constructs such as discourses, positioning and power dynamics are less inter-related (Prediger, Bikner-Ahsbahas and Arzarello, 2008; Skog, 2012; Ryve, Nilsson and Mason, 2012; Skog, 2014). The methodological choice in this investigation was a critical success factor upon which the methods for conducting this research were built.

4.3 RESEARCH DESIGN

Figure 4.5 illustrates the iterative instructional design approach (Dick, Carey and Carey, 2014) that guided the construction, the implementation and the administration of the mathematics intervention.

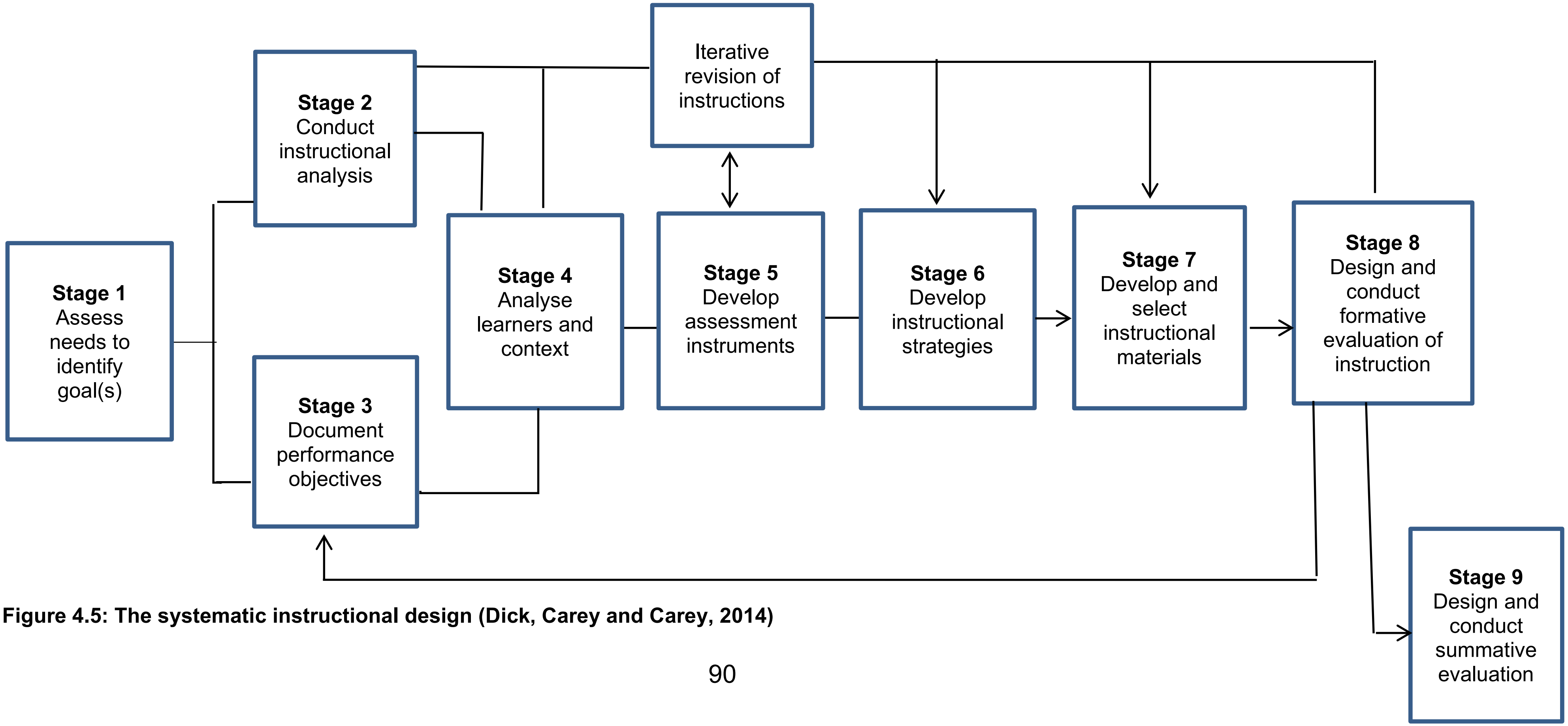


Figure 4.5: The systematic instructional design (Dick, Carey and Carey, 2014)

Figure 4.5 demonstrates the nine stages incorporated as aspects of the instructional research design that guided the construction and the implementation of the mathematics intervention.

Stage 1: Assess needs to identify goals

The students' levels of experience in solving foundational arithmetic problems and their practical mathematical skills were assessed using their pre-test scores. Empirical research and discussions about the teaching of mathematics support the notion of an active and social approach to teaching and learning mathematics (Keitel, 1989; Ernest, 1991; Seeger, Voigt and Waschescio, 1998). During the four-day induction programme, the IT students underwent a basic to intermediate Microsoft Excel course. The students' IT skills were assessed with the help of the IT technicians support team at the university where this study was conducted. Experts in the IT domain were interviewed to determine their views regarding the numeracy skills of IT students in transit from high school to university.

Stage 2: Conduct instructional analysis

All lecturers who taught first-year IT students in the HCINCT programme were consulted. The content of the discussions held regarding their course objectives was documented and thereafter, a learner guide was constructed in line with these objectives. The students' performance objectives were documented in line with the performance objectives defined by the university in the general handbook. The use of social media in teaching mathematics plays a pivotal role in participatory learning if proper guidelines are used for the selection and the application of social media tools (Conley, Lutz and Padgitt, 2017). Therefore, the performance objectives were linked to the use of social media both on and off campus. The UoT where this investigation was conducted has a set of rules and regulations. The documented criteria for setting assessment grades were used to align the QT course to the university's criteria for passing or failing students.

Stage 3: Document performance objectives

This stage clarified the goals that were set to establish SWBAT, which stands for "students will be able to …" The IT Department expected each student in the HCINCT programme to achieve an overall 60% aggregate mark in order to be administered into the IT National Diploma the year after the MCI programme. These objectives were aligned to the objectives that were set for the QT course content. Quantitative Techniques was the main course through which the class tutorials were administered.

Stage 4: Analyze learners and contexts

The overall marks of students in the HCINCT programme upon entry into the mathematics intervention were lower than the entrance mark set by the IT Department, as seen in Chapter 1. The students' matric results were assessed and comparisons were drawn between their marks on entry and their attained marks in the pre-test. Past matric examination papers for the years 2010 to 2014 were assessed for relevance to the requirements of the QT course at NQF level 5 (South African Qualifications Authority, 2012) and to establish the gap in the levels of students' mathematical skills in transit from high school to university. Based on the knowledge attained from the students' matric and pre-test scores, a teaching method that addressed the students' mathematical needs was designed.

Stage 5: Develop assessment instructions

Information Technology technicians and e-learning personnel were consulted and arrangements were made to train the IT students on the effective use of the university learner management systems both on and off campus. Students were allowed to download smaller files to take home, thus enabling the students who did not have Internet access at home to work on their QT class tutorial exercises outside the QT labs. The materials for the QT course were aligned with the objectives of other courses within the HCINCT foundation programme in order to cover the mathematical skills that were indicated as missing in the students' pre-test scores. Video materials covering high school Mathematics and the level after high school but before university known as NQF level 5 (South African

Qualifications Authority, 2012) were sourced and loaded onto the student learner management system for ease of access by the students.

Stage 6: Develop instructional strategies

The instruction design was used to build strong conceptual knowledge, to bridge overlapping knowledge domains and to link subject matter knowledge to pedagogical content knowledge (Ball, 1988; Stodolsky, 1988; Borko, Whitcom and Liston., 2008). Teaching methods were improved to ensure that the course curriculum was communicated clearly and visually to both the lecturer and the students (Artigue *et al*., 2002; Davies, 2013; Artigue, 2014) The active experimentation stage of Kolb (2015) was considered a try-out stage for the research participants.

Learning strategies that tested learning through assessments and simulation in the HCINCT programme were built. Collaborative learning was implemented to harness individual learning and to enhance institutional education governance (Zuber-Skerritt, 2005). Many repetitive learning strategies were tried and tested until the lecturer and the students felt that a particular strategy produced quicker results. The time aspect in the mathematics intervention was a critical factor because the QT class tutorials were an addition to the QT course offered in the HCINCT programme.

Stage 7: Develop and select instructional materials

A lesson plan was developed and linked to the QT class tutorials. Media lecturers and IT technicians were consulted to determine how one could use media to transfer mathematical skills effectively. Existing websites such as the Khan Academy and YouTube were explored. Instructional materials taught students how to apply mathematics rules, axioms and formulae to mathematics problems systematically from worked examples and how to engage their learning through doing (Zhu and Simon, 1987; Sweller and Cooper, 2009).

The latter was conducted to foster students' understanding of the mathematics language and its connection to the mathematics problem and the consequent building of students' skills to solve life problems using mathematics rules and axioms (Menon, 2014). The aim was to use practical mathematics to structure a way of reasoning and to scaffold first-year IT students' mathematical capabilities. Many teaching strategies were tested and finally, the researcher selected a few that suited both the students and the researcher. Different methods for solving a mathematics problem were documented.

Stage 8: Design and conduct formative evaluation of instruction

Reflective learning is the key to learning from experience and is a process that is central to learning mathematics (Boyd and Fales, 1983; Brockbank and McGill, 2007) Thus, reflective learning requires the ability to extend surface learning into deep learning using correct questioning techniques (Bourner, 2003). The students and the lecturer reviewed and reflected upon the experiences described by the students through their interaction with mathematics content.

The researcher closely interacted with the students regularly and this allowed for multimodality and embodiment of the development of students' cognition in mathematics (Arzarello, 2006). Mathematical dialogues were enhanced in the students by applying content and practice experientially. The class interactions and student dialogues during the mathematics interactions were narrated in a manner that the class interactions with mathematics depicted the original classroom setting in which the interactions occurred (Linell, 1998; Röj-Lindberg, 2001).

Stage 9: Design and conduct summative evaluation

A post-test was designed with the topics that were used in the pre-test. The students took this test voluntarily, but it was a summative assessment. The students were not allowed to use calculators. Post-test writing conditions were simulated to be exactly as they were when the students took the voluntary pre-test. The students' scores were not for marks; they were used only for the purposes of the investigation. The responsibility of every society and every educational institution is to improve the education and the thinking of its citizenry (Qarareh, 2012).

In this investigation, constructive alignment principles were used to gain the intended learning outcomes in the QT class tutorials (Biggs, 1996). The test solutions were examined by the researcher after each administered intervention. This initiative encouraged students to check their solutions to the problem against the models and to reflect on their miscalculations or process any omissions. The students were encouraged by the researcher to ask questions and to try to solve the mathematics problems on their own.

Soon this became the norm and the students took to the blackboard with chalk, discussing and arguing with each other while laughing and engaging with content materials. Abstract conceptualisation relates to the teachers' abilities to provide constructive and helpful feedback to students on time. Giving students' feedback on time encourages learning and allows for early depiction of learning problems (Moylan, 2009; Carvalho *et.al*, 2015; Muis, Ranelluci, Trevors and Dufy, 2015).

On inception into the enhancement of the mathematics intervention, students gained access to the learner management system (Blackboard) where all the year's work was uploaded. In the third term of the QT course work, there was a group project for the first-year IT students in the HCINCT foundation programme. A significant component of the project was a Microsoft Excel group assignment that accounted for 40% of the third-term marks. For this Microsoft Excel project, students worked in groups of eight to nine people and displayed their newly acquired tools for quantitative techniques.

Students created and submitted their group project in four phases over a period of four weeks. The researcher provided feedback to the student groups after each phase. Each group was permitted to progress to the next phase of the project once the researcher had marked the previous phase and the group had rectified the errors and justified their actions and/or decisions. These stages were used to direct, implement and administer the mathematics intervention programme in the HCINCT programme of 2015.

4.4 METHODS

A mixed methods approach is useful to gain the positive attributes of both quantitative and qualitative methods for data collection, data analysis and data presentation (Creswell, 2009; Merriam, 2009; Patton, 2014; Verhage and Boels, 2016). The use of multiple methods neutralises and cancels the negative aspects of each method (Morse, 2003; Tashakkori and Creswell, 2007; Tashakkori and Teddlie, 2010; Maxwell and Mittapalli, 2010). Quantitative and qualitative forms of data were integrated to gain a fuller understanding of the research problem (Tashakkori and Creswell, 2007; Leech and Onwuegbuzie, 2009; Creswell, 2013).

4.4.1 Quantitative approach

This research sought answers to the research questions by identifying a gap in the knowledge. To achieve this, the study used numbers as the basic unit of analysis and employed statistical analysis and generalisation (Meadows, 2003; Creswell, 2014; Hall and Quick, 2015). Quantitative instruments were used to assess the data derived from the students' pre-test and post-test scores. Both assessments were formative and were written at different times. Students voluntarily underwent the assessments and the assessment scores were not for academic use. This was communicated to the students in advance. The pre-test was administered to the students upon entry into the HCINCT programme. The post-test was administered to the students on completion of the HCINCT programme.

4.4.2 Instruments for data analysis

Initially, the researcher selected the pre-test and post-test research design to collect data from the students (Thomas and Nelson, 2001). Figure 4.6 demonstrates the pre-test and post-test research design.

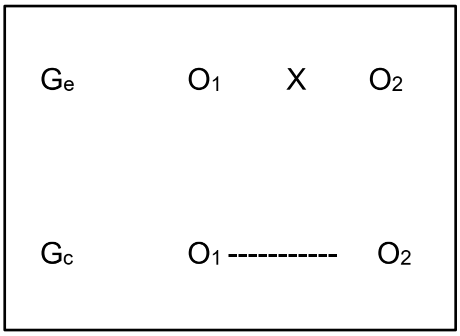


Figure 4.6: Pre-test and post-test research design

O_1 = Pre-test; X = Treatment; O_2 = Post-test; G_e = Experimental group; G_c = Control group

Finally, the pre-test post-test research design could only allow one experiment group and one control group. This would mean allocating uneven groups numbers to the experimentation groups because there were 26 students that did not arrive to take the pre-test. The researcher found the Solomon's four group research design appropriate for randomly assigning students to groups for the pre-test and post-test assessments (Solomon, 1949).

Table 4.1 illustrates Solomon's four group design.

Table 4.1: Solomon's four group design (Solomon, 1949)

Groups	Pre-test	Treatment	Post-test
Experimental (E_1)	O_1	X	O_2
Control (C_1)	O_1	____	O_2
Experimental (E_2)	_____	X	O_2
Control (C_2)	_____	_____	O_2

O_1 = with pre-test; X = with treatment; O_2 = with post-test; __without treatment

Table 4.1, illustrates the use of Solomon's four group design guidelines (Solomon, 1949) to randomly assign the N = 147 IT students to two experimental groups and to two control groups. Thirty-seven students were randomly assigned to the experimental group (E_1). Thirty-seven students were assigned to the control group (C_1). Thirty-seven students were randomly assigned to the experiment group (E_2). Thirty-six students were randomly assigned to the control group (C_2). There were two pre-test groups and two without pre-test groups. The aim for setting the groups this way was to measure change if any with the pre-test and post-test data

Additional details regarding the instruments for data analysis section are presented in Chapter 5. The study mainly used bivariate descriptive analysis, explanatory analysis and inferential analysis to interpret the data (Creswell, 1998; Wagner, 2000; Blaike, 2003; Kothari, 2004). Descriptive and inferential statistical tools were used to describe the form and strength of associations between variables. Moreover, descriptive and inferential statistical tools helped to estimate whether or not the attributes or relationships found in the sample group of the investigation were different from those expected in the population from which the sample originated (Kothari, 2009). The statistical tools were combined to establish the direction and strength of influence between variables. Therefore, the quantitative data analysis procedures above allowed for the generalisation of sample statistics back to its population parameters. Labels were used to analyze emerging clusters and model-based clustering.

4.4.3 Data analysis

The student assessment scores gained from the pre-test and the post-test were captured onto MS Excel and imported to the Statistical Package for the Social Sciences (SPSS) software (version 25) for analysis and interpretation. The SPSS output data were used, analysed and interpreted. Thereafter, the information that was derived from the student pre-test and post-test scores was presented. Student scripts were used as evidence and literature was referenced. A tentative answer was presented and its connection to the literature reviewed was shown with supporting literature.

4.4.4 Sampling

Comparative profiling systems were conducted to compare the students' assessment scores and thus determine the efficacy of the MCI (Sandelowski, 1995; Sandelowski, 2000). A series of formative assessments were administered to the students to gauge their mathematics levels prior to administering the pre-test. The post-test was conducted to ascertain if the students had acquired the desired skills and to measure the percentage increase/decrease in their mathematics scores when compared with their scores upon entry into the mathematics intervention programme.

The ratio of 3:3:2:3 was used to categorise the students' assessments scores that were used as evidence in Chapter 4. The categorising of students' scores was conducted to attain a range of assessment scores comprising high-, middle- and low-range marks (Wiersma and Jurs, 2009). This was done so that the analysis reflected a true picture of the students' mathematical capabilities and allowed generalizability of the results to the population from which the sample group was drawn. The sampling strategy was used in the investigation for identifying, selecting, contrasting and searching for variation among information-rich cases (Miles and Huberman, 1994; Tashakkori and Teddlie, 2003; Curran, Bauer, Mittman, Pyne and Stetler, 2012).

4.4.5 Quality control of the quantitative findings

The ELT, the instructional design model and the mixed methods sequential explanatory design approach were adopted in pursuit of answers to the research question in order to find a solution/s to the research problem (Wiersma and Jurs, 2009; Creswell, 2009; Creswell, 2014). This study followed an experimental research method using a quasi-experimentation pre-test/post-test control group design to evaluate the students' mathematical capabilities before and after the enhancement of the students' mathematical capabilities through QT tutorial classes in 2015 (Cochran and Cox, 1957; Kenny, 1975). This was done to determine relationships, effects and causes, if any.

(a) Internal validation

Internal validation was judged by building a quality control process within the data collection, data analysis, data interpretation and data analysis processes. The data outputs were checked for consistency and transferability to ensure that the findings of the results provided answers to the research questions. The answers to the research questions needed to be believable, realistic, credible, transferable, dependable, generalizable, confirmed and consistent with previous research outputs (Lincoln and Guba, 1985; Guba and Lincoln, 1994).

(b) External validation

The findings were externally validated to establish the extent to which they applied to other situations discovered during the investigation of the enhancement of mathematical capability (Merriam, 2009). Only the data outputs of the 147 research participants were determined for generalizability as opposed to referring to the entire student population of the IT Department (Neuendorf, 2002). Neither volunteers nor external people were engaged to administer the data. The researcher conducted the research and administered the data personally.

4.4.6 Qualitative approach

Once permission was granted, the researcher used a laptop and downloaded the Skype call recording software to record the interview responses of the 11 purposefully selected students. The researcher sought to understand through qualitative methods what students considered to be the real problems regarding their missing/lost mathematical capabilities. Nine questions were posed to the respondents (see appendix I). The questioning style was open-ended to allow the students to express their opinions and to engage with the questions because open-ended questions elicit general reactions on the subject from respondents (Willig, 2008; Merriam, 2009; Struwig and Stead, 2013).

Permission to use an audio machine for recording the students' responses during the interviews was sought from each student by the researcher (Merriam, 2009; Omrord, 2010). The researcher dedicated her full attention to listening to the students' interview responses. One hour was allocated to interview each research participant. One-on-one semi-structured interviews and two case study materials (Merriam, 2009; Yin, 2015) were utilised to gather data that were used to understand the phenomenon under study. The researcher affirmed confidentiality with each student and explained that the audio recordings were merely to enable the researcher to refer back to answers during the data analysis process (Patton, 2002).

4.4.7 Instruments of analysis

One-on-one interviews were used for interviewing the students. The questioning style was open-ended to allow the participants to express their opinions and to engage with the questions because open-ended questions elicit general reactions on the subject (Willig, 2008; Merriam, 2009; Struwig and Stead, 2013). Although the students had limited time to attend an interview due to their time schedules and the fact that it was examination time, they agreed to a one-hour interview per student. On the contrary, in-depth interviews were conducted with the two professors from the two UoT's in Northern Europe. These in-depth interviews allowed the construction of understanding since the researcher had more time to ask additional questions and to visit locations repeatedly. Two case studies were used to understand the missing mathematical skills in the IT students.

The following six interview questions (Appendix H) were posed to explore perceptions of the IT domain experts:

1. How are the mathematics capabilities of first year IT students on entry at the UoT?
2. What do you think is needed to enhance the students' mathematics capabilities?
3. Which numerical skills do you think the students lack on entry into the UoT to study IT programming studies?
4. In your view do the students need numerical capabilities to study IT programming studies at the UoT where this study conducts?
5. Could you comment on your experiences with IT students' numerical abilities during their IT programming studies?
6. How have you experienced the overall mathematical capabilities of 3rd year and fourth years IT students at the UoT?

4.4.8 Data analysis

A three-step process was used to analyze the qualitative data. In step one; open coding was used to read the one-on-one interview responses of the students. Step two, after reading the participants' qualitative data inputs, the data were chunked based on meanings that emerged from the data (Gallicano, 2013). The students' responses were recorded by words to find properties to allocate codes (step three). Step three involved axial coding in combination with content and thematic analysis to identify relationships among the open codes established in step one and step two above.

Thematic and content analysis served different research purposes in this investigation. For example, thematic analysis provided an interpretation of participants' meaning. In contrast, content analysis was used for directly presenting participants' responses (Crowe, Inder and Porter, 2015; Castano, Ferrara and Montanelli, 2017). Content analysis was chosen for its strengths rather than its limitations; it is dependable and has internal validity

(Neuendorf, 2002; Krippendorff, 2004; Yang and Miller, 2008). However, unlike axial coding, content analysis uses theory, which attends to the aspects of trustworthiness, reliability and validity of data. In addition, content analysis guided the initial codes that were obtained earlier in the data analysis process. The last step (step three) was selective coding in which core variables were chosen from the variables that emerged in the previous steps. Selective coding often tends to add depth in data analysis (Walker and Myrick, 2006; Corbin and Strauss, 2008; Hardman, 2012).

Coding is used for data analysis to open text and to expose the thoughts, ideas and meanings contained therein (Babbie, 2013). Once these meanings within the data were established, data interpretation took place; this was done to convert the data into valuable information. During data interpretation, the data were grouped into the five constructs that emerged from the second literature review as demonstrated in Figure 4.7.

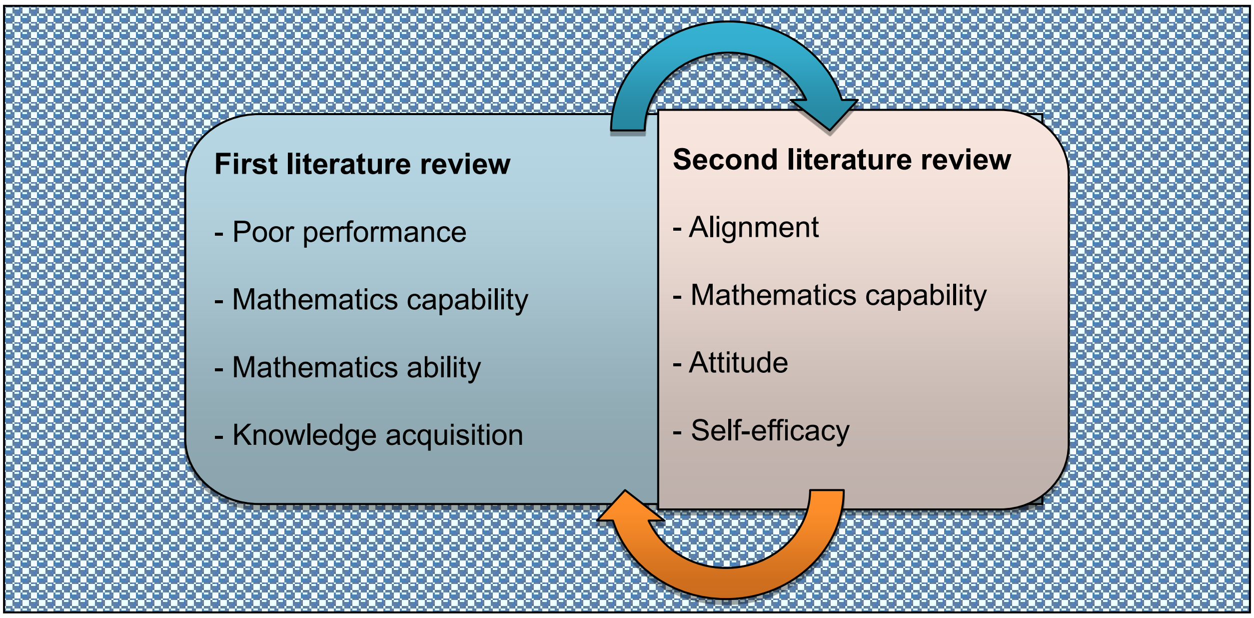


Figure 4.7: Constructs from second literature review

The findings in Chapter 5 are presented using the constructs shown under the second literature review in Figure 4.7. These constructs were the outcome of the second literature review that was conducted after interviewing 11 students selected from the QT class tutorial group in the HCINCT programme of 2015. The qualitative findings were presented using research questions that were compiled using the constructs that emerged from the literature reviewing process in chapter 2 of this research document. Creswell's mixed methods sequential explanatory design (2013) illustrated through Figure 4.8 was used to structure the findings of the results in Chapter 5.

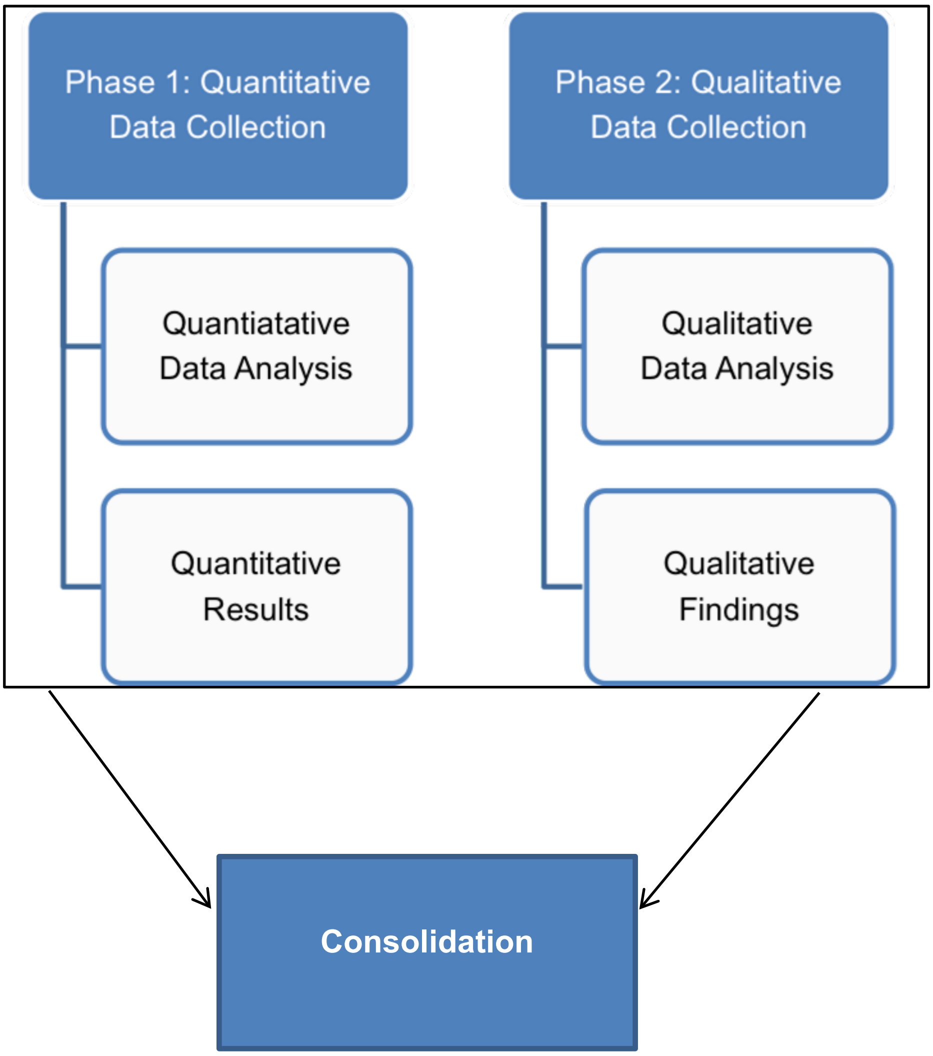


Figure 4.8: Sequential explanatory design (Creswell, 2013)

Guidelines extricated from the mixed methods sequential explanatory design (Creswell, 2013) were used to present the findings of this investigation.

4.4.9 Sampling

Purposeful sampling strategy was used to identify, select and enhance comprehension of the information-rich case through the development of idiographic knowledge (Wagner, 2000; Patton, 2002 Creswell, 2009). A suggestion is that between 5and 20 people should be interviewed for a qualitative research investigation (Merriam, 2009). However, in this study, 11 purposely selected research participants were interviewed to try and understand what the research participants thought about their mathematical skills (Sandelowski, 2000; Worthley, 2007; Lopez-Fernandez and Molina-Azorin, 2011). The number of participants decided upon was between 20% and 30% of the sample group (Lincoln and Guba, 1985; Wagner, 2000; Patton, 2002). The students who were interviewed were chosen according to their scores in the pre-test.

The ratio of 3:3:2:3 was used to categorise students' assessment scores as high, middle and low. This was done so that there would be a range of assessment scores (Wiersma and Jurs, 2009). The sampling strategy was used in the investigation for identifying, selecting, contrasting and searching for variation of information-rich cases relating to the MCI and its success (Miles and Huberman, 1994; Patton, 2002; Tashakkori and Teddlie, 2003; Curran, Bauer, Mittman, Payne and Stetler , 2012).

4.4.10 Quality control of the qualitative findings

This section reviews credibility, transferability, confirmability and reliability.

Credibility

The researcher considered the credibility of the data by how accurately the data reflected the reality of the enhancement of the MCI. However, one needs to guard against research participants who change their behaviour during the research process because this results in a Hawthorne effect and distorts the data (Omrord, 2010). Fortunately, in this investigation, no students changed their behaviour during the study. To increase data credibility, the scribed notes taken from the recorded interview sessions with the 11 purposefully selected students were verified during the data collection phase.

The data collection process was emphasised through transparent and open communication with the students regarding the intentions of the investigation. . Checkpoints were built into every step of the project to avoid sampling bias (Thomas and Nelson, 2001). Bias was avoided and interviewees voiced their true perceptions of how they felt about the enhancement of the MCI. Peer debriefing was encouraged to promote open and clear communication.

Transferability

The researcher informed the students about the purpose of the study and the reasons why their involvement in the investigation was important (Merriam, 2009). The students were informed that it was acceptable to decline the offer to participate before or at any time during the investigation (Neuendorf, 2002). It was also explained to the students that should they decide not to continue with the investigation, their data would be discarded and excluded from the investigation (Fieser, 2017).

Students were asked to give the researcher permission to use a recording device and permission was granted. The importance of using a recording audio device during the interviews was explained to the research participants (Patton, 2002). The collected data were dependable and truthful and the interpretations of the data were generalizable back to the population from which the sample was taken (Neuendorf, 2002; Creswell, 2009).

Confirmability

The results of the findings obtained using the qualitative methods were rigorously assessed for confirmability and reflexivity to ensure quality in the qualitative process used in the analysis and interpretation. Confirmability was also addressed to monitor the researcher’s subjectivity in generating credible findings (Darawsheh, 2014).

Reliability

Ultimately, one embarks on an investigation to obtain results that are consistent and reliable. The results of the findings of an investigation are expected to be consistent and trustworthy (Neuendorf, 2002). Therefore, the methods that were employed to collect, analyze and interpret the data were carried out with precision to ensure that the quality of the data output produced results that were sincere and showed a true reflection of the circumstances during and after the enhancement of the MCI programme. In addition, the results were checked for reliability so that answers to the research questions could be generalised to the population from which the samples came (Wiersma and Jurs, 2009; Darawsheh, 2014).

4.4.11 Verification of the results of the findings

Triangulation of research methods

To check for irregularities in the research data, triangulation of methods was used to cross-check information from students' responses in the interviews, the comments of the IT domain experts and the student assessment scores. This was done to produce accurate and consistent data that revealed a more detailed and well-balanced picture about the enhancement of the mathematical capability of the 147 IT freshmen at the UoT (O'Donoghue and Punch, 2003; Altrichter, Feldman, Posch and Somekh, 2008).

The students' interview responses were triangulated with their pre-test scores. The triangulation of the students assessment scores with the one-on-one students interview responses was done in an effort to map out and to clarify more fully the richness and the complexity of the students and their engagement in acquiring mathematical capabilities, thus enabling the students' views and opinions to be heard (Cohen and Manion, 2000).

In addition, the interview responses gained from the IT domain experts offered the opportunity to check if there were common or uncommon trends emerging from the data – collected from both students and IT domain experts. The reason for using triangulation was to increase the credibility and the validity of the findings of the investigation (Creswell, 1998; Angen, 2000).

Data triangulation

To ensure credibility and validity through data triangulation, the researcher (i) allocated each student an equal interview time of one hour; (ii) ensured that the same space existed between herself and the student in each interview; and (iii) used the same venue for all the interviews. Moreover, in selecting students' scripts to use as evidence in Chapter 4, the researcher chose scripts from the group of 11 students that had been purposefully selected. According to Denzin (2006), data triangulation involves time, space and persons. The data that were derived through mixed methodology were checked for consistency, validity, conformity and reliability.

4.5 ETHICAL CONSIDERATIONS

The researcher obtained ethics clearance in July 2016 from the ethics clearance committee of the UoT where the study was conducted. In September 2016, a formal letter seeking voluntary participation was drawn up and distributed to persons. A specimen of the letter is attached to this document (see appendices G). Once students had given their consent through signature, the researcher purposefully selected 11 research participants and scheduled a one-hour, one-on-one, semi-structured interview with each (Corbin and Strauss, 2008; Baxter and Jack, 2008). There are ethical risks associated with conducting research with one's own students since one is both the researcher and the instructor (MacLean and Poole, 2012).

Informed consent and the student's right to participate or to withdraw from the research process were explained to the students (Morse, 1991). The students were given factual and sufficient information in regard to the research and their involvement (Bergen and While, 2000; Polit and Hungler , 2001; Polit and Beck, 2016; Polit and Beck, 2018). The participants were informed that they were free to abandon the research process whenever they wished and should they decide to withdraw from the research process, their information would be discarded. The research ethical consideration was addressed with the students during the data collection phase. The data were kept in a locked safe at the UoT and the students' identity was undisclosed.

The time and a budget for the project were considered and a grant was sourced to cover the financial aspects of the investigation (Herrington, McKeeney and Reeves, 2007). A sponsor was sourced to collect data abroad via the case study method at a UoT that had run a similar and successful intervention process. This was conducted in line with study of the European UoT MCIs so that the researcher could consider time and budget while contemplating the ethical aspects of the research. In research, if these aspects are left unattended, they could have an impact on the delivery of the research project.

4.5.1 Permission to use student data

Permission was sought from the university's ethics committee to use the students' data and assessment scores for this investigation. Permission was granted in July 2016. An ethics clearance letter from the university's ethics committee is attached towards the end of this document (see Appendix G).

4.5.2 Student consent

The intervention was incorporated into the students' regular classes. Students were aware that QT was a subject in which the enhancement of mathematic capability was administered. However, students could choose not to take the QT class tutorials since there was a clear distinction between the structure of the QT course content and the sections that counted towards the mathematics intervention programme through QT. In September 2016, students were presented with letters asking for them to partake in the survey study. The students agreed to participate in the investigation. The survey questionnaire was administered to the research respondents during their Network Foundations 2 class tutorial with the permission of the subject lecturer.

4.5.3 Dual role: Researcher and instructor

This investigation had no conflict of interest for the researcher because the investigation was not for the researcher's personal development. The mandate to conduct this study was obtained by the researcher from the project sponsor in January 2015 Alexander,

(2013) where this study was conducted wanted the study to be conducted to determine the feasibility of fulfilling the government mandate given to the project manager and subsequently, to hand over the intervention to FET colleges at the end of the 2015 academic year, now known as TVET colleges (Alexander, 2013; Department of Higher Education and Training, 2013). There group of 147 students participated in this investigation of which 74 were placed into two experimental groups and 73 were placed into two control groups. Eleven students that participated in the qualitative one-on-one interviews were purposefully selected from the n=147 students.

Furthermore, the research was not intended for public use but for internal use by the UoT to increase learner retention and the throughput rate of IT students (Higher Education Data Analyzer, 2016). In 2015, the researcher taught the students during the course of the HCINCT programme. Data collection and the student interviews were conducted in 2016 during this time the students had already completed their studies in the HCINCT programme and the lecturer was working as a researcher and had no connection to the students.

4.5.4 Use of own classroom in research

The MCI of 2015 study was conducted in the instructor's classroom. However, the classroom conduct did not contravene the ethics since all work done was mandated. In addition, the investigation was carried out for the purposes of the university and the documentation produced research materials that were not for public use. The students' outputs and the research materials derived during this investigation were kept safely at the UoT.

4.6 CONCLUSION

The instructional design model, the literature reviewed, the theoretical framework (ELT) and the mixed methods instruments were used in this investigation to gain answers to the research questions. The research questions and the research objectives guided the process of investigation in search of solutions to the research problem. The gaps that were determined through the literature reviewed were addressed and answers to the research questions are presented in Chapter 5 of this document. By answering the research questions, the research objectives were accomplished. The following chapter presents the results that were attained using mixed methods instruments for analysis.

5 CHAPTER 5: FINDINGS

5.1 INTRODUCTION

The purpose of this study was to investigate the efficacy of the MCI administered to first-year IT students in the one-year HCINCT programme in 2015. One main research question and five sub-questions directed this investigation. Data were evaluated using mixed methods tools as described in Chapter 3 (Tashakkori and Teddlie, 2003; Creswell, 2009; Lopez-Fernandez and Molina-Azorin, 2011; Creswell, 2013; Agerfalk, 2013). Pre-test and post-test assessment scores of the students from the 2015 HCINCT, together with the one-on-one interview responses from the South African UoT students were evaluated to find answers to the research questions of this investigation.

5.2 STUDENT DEMOGRAPHICS

The student demographics for this study encompassed registered first-year IT students in the HCINCT programme (n = 147). The students' mean age was 19 years and 32% were females and 68% were males. Figure 5.1 shows the students' retention rates at the end of the mathematics intervention treatment (the treatment).

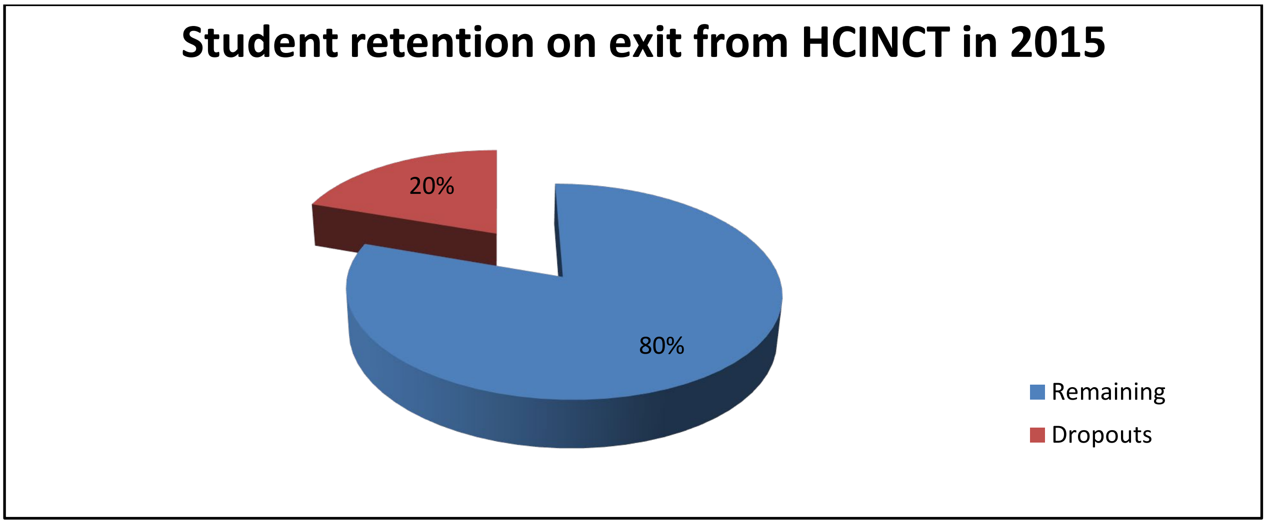


Figure 5.1: Students' retention rates on exit

The entire student's population from which this sample was drawn from is illustrated in Figure 5.2 in the next section.

5.3 STUDENT POPULATION

There were 32 887 registered students at the UoT in 2015. The Cape Town campus contributed 49% of the student population, while the remaining 51% comprised students registered at the other four campuses. This investigation focused on a sample of students from the Cape Town campus. Figure 5.2 demonstrates the faculties in which the students were enrolled.

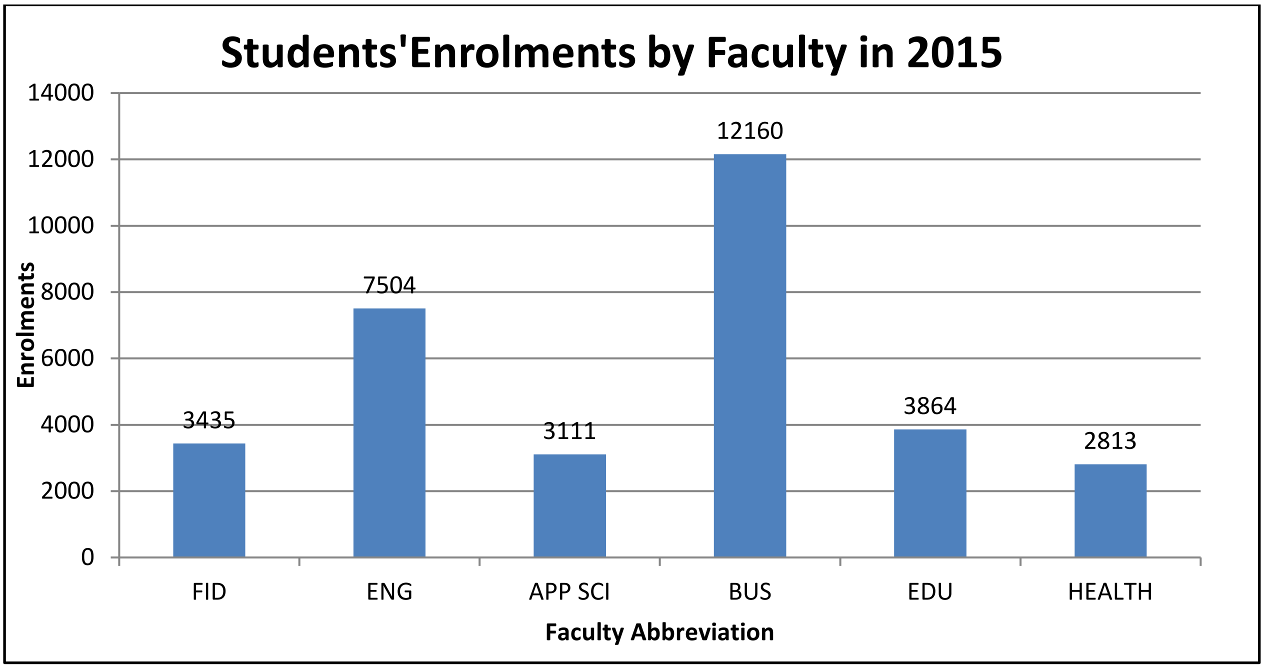


Figure 5.2: Student enrolment at the university of technology in 2015 (Higher Education Data Analyzer, 2016)

Figure 5.2 illustrates six faculties across which the student population is spread. The Faculty of Informatics and Design (FID) located in the Cape Town campus contributes 10% of the entire student population. The sample was drawn from the IT Department, a division of the FID. In the next section the research questions are revisited. The main research question and sub-questions 1, 2 and 3 were answered using quantitative instruments for data analysis. Sub-question 4 was answered using both quantitative and qualitative (mixed methods) instruments for data analysis. Tables 5.1, 5.2 and 5.3 conveniently repeat Tables 1.2, 1.3 and 1.4 presented earlier in Chapter 1. They revisit the research questions of the study. These tables display the research questions, related hypotheses and the research objectives.

Table 5.1: Quantitative Research Questions, Hypotheses, Objectives and Data Analysis Instruments Main and Sub-Questions1 and 2

Quantitative Research Questions	**Hypotheses**	**Objectives**	**Data Analysis Instruments**
Main Research Question *What is the effect of the intervention programme on the IT students upon entry into the HCINCT programme?*	**Main Null Hypothesis (Ho)** There is no statistically significant difference between the groups' mean scores before and after the MCI. **Main Alternative Hypothesis (H_a)** There is a statistically significant difference between the groups' mean scores before and after the MCI	**Main Objective** To establish if the intervention was successful in enhancing the students' mathematics capabilities through the QT class tutorials in 2015	Pre-test and post-test assessment scores
Sub-Question 1 *Are the post-test scores of all groups statistically different?*	**Sub-Question 1 Null Hypothesis (Ho)** The means of each group are the same. **Sub Question 1 Alternative Hypothesis (Ha)** There is a mean difference between at least two groups.	**Objective 1 Sub-Question 1** To establish whether or not the mean post-test scores of the four groups were significantly different	Post-test assessment scores
Sub-Question 2 *What evidence do we have to suggest that the sample came from a population such that the mean score was 50?*	**Sub-question 2 Null Hypothesis (Ho)** There is no statistically significant difference between the mean score of the UoT students and the mean score of the HCINCT students. **Sub-Question 2 Alternative Hypothesis (Ha)** There is a statistically significant difference between the mean score of the UoT students and the mean score of the HCINCT students.	**Objective 2 Sub-Question 2** To establish if the sample mean score in HCINCT is a true parameter that represents the IT students' population mean score in 2015	HCINCT 2015 final-year students assessment scores

Table 5.2: Quantitative Research Questions, Hypotheses, Objectives and Data Analysis Instruments Sub-Question 3

Quantitative Research Questions	**Hypotheses**	**Objectives**	**Data Analysis Instruments**
Sub-Question 3 *Is there a statistically significant difference between the HCINCT 2016 mean score on exit and the HCINCT 2015 mean score on exit?*	**Sub-Question 3 Null Hypothesis (Ho)** There was no statistically significant difference between the mean score of the HCINCT 2016 students and the mean score of the HCINCT 2015 students on exit. **Sub-Question 3 Alternative Hypothesis (Ha)** There was a statistically significant difference between the mean score of the HCINCT 2016 students and the mean score of the HCINCT 2015 students on exit.	**Objective 3 Sub-Question 3** To evaluate if the intervention made a statistically significant difference in enhancing the students' mathematical capabilities	HCINCT 2015 and HCINCT 2016 students' assessment scores

Table 5.3: Mixed Methods Research Questions, Hypotheses, Objectives and Data Analysis Instruments Sub-Question 4

Mixed Methods Research Questions	**Hypotheses**	**Objectives**	**Data Analysis Instruments**
Sub-Question 4 *Under which circumstances did the students results improve?*	**Sub-Question 4 Null Hypothesis (Ho)** There were no circumstances that indicated improvements had been achieved in the students' results. **Sub-Question 4 Alternative Hypothesis (Ha)** There were circumstances that indicated improvements had been achieved in the students' results.	**Objective 4 Sub-Question 4** To establish the criteria for successfully addressing improvement to the students' mathematics results	Interview responses of students in a South African UoT and teaching strategies together with the feedback from experts from the IT domain.

The methods of data analysis and data presentation that were sourced through the research instruments demonstrated here and positioned earlier in Tables 1.2, 1.3 and 1.4

Figure 5.3 illustrates the mixed methods sequential explanatory design (Creswell, 2013), mentioned in Chapter 4 and used to present the findings.

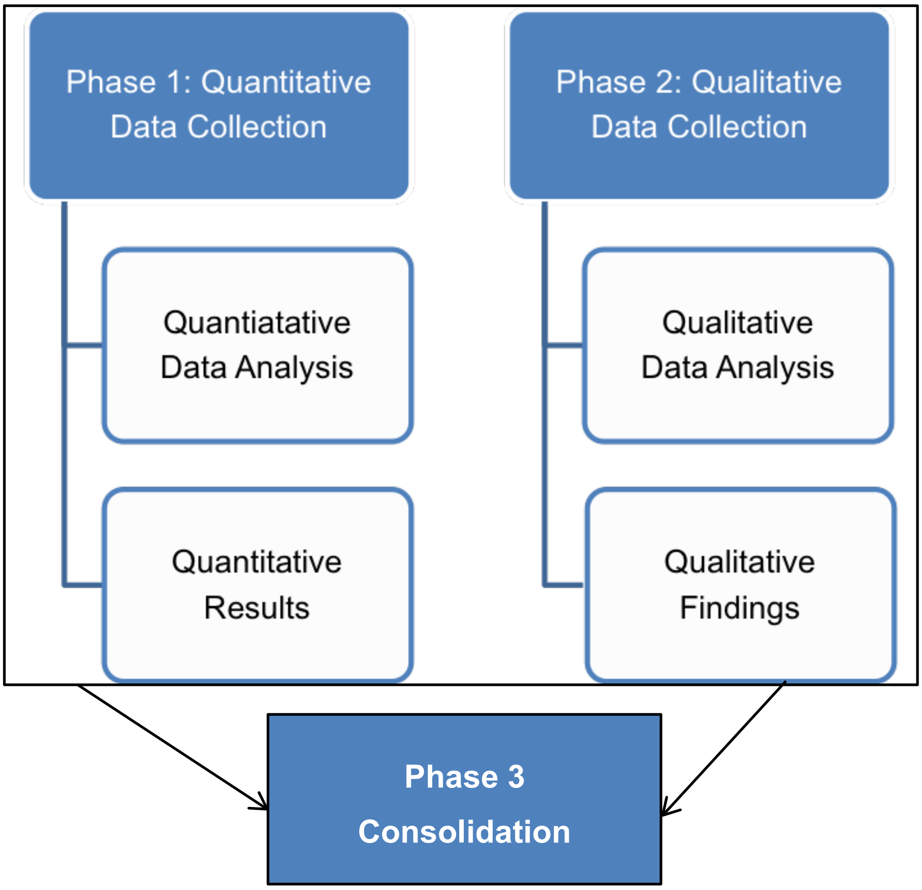


Figure 5.3: Mixed methods sequential explanatory design (Creswell, 2013)

The guidelines demonstrated in Figure 5.3 are used to structure the data analysis and data presentation discussion in this chapter.

5.4 FINDINGS REPORTING STRUCTURE

Findings of the study are reported in three phases. Phase 1 presents findings associated with the main research question and sub-questions 1, 2 and 3. Phase 2 addresses sub-question 4 while Phase 3 presents the amalgamation of the mixed methods findings.

5.4.1 Phase 1: Quantitative Data Collection

The main research question and sub-question 1 were tested using the pre-test and post-test assessment scores of the 2015 IT students. Sub-question 2 hypotheses were tested using the final-year assessments scores of the HCINCT 2015 students. Sub-question 3 hypotheses were tested using the final-year assessment scores of the HCINCT 2015 and HCINCT 2016 IT students. Sub-question 4 hypotheses were tested using the students' scripts and the teaching strategies.

Quantitative data collection

Pre-test scores were collected at the start of the MCI. Data regarding the students' post-test and final-year assessment scores were collected at the end of the MCI (the treatment). This was done after an ethics clearance letter was received from the Faculty Research Ethics committee of the Cape Peninsula University of Technology (see Appendix G). The researcher received a formal letter from the UoT's Acting Vice Chancellor in July 2016. The letter granted the researcher permission to use the assessment scores of the IT students for the purposes of this investigation. The data were retrieved electronically from the assessment centre database of the university using a secured username and password.

All confidential information regarding the students was removed from the students' scores report data. The researcher replaced the students' personal information with arbitrary ID numbers in the MS Excel spreadsheet. Thereafter, the students' scores were copied into a password-protected MS Excel spreadsheet. All data collected were captured and stored in such a way that there was no possibility of identifying individual students. Pre-test and post-test assessment scores were stored electronically using a protected password that was known to the researcher only. All these security steps were implemented in compliance with the data security and protection policies of the UoT.

Quantitative data analysis

Data analysis for the South African HCINCT 2015 student group began in January 2017. Descriptive statistics data were gained using IBM SPSS version 25 software.

5.4.2 Phase 2: Qualitative Data Collection

Nine research questions were compiled using the research constructs of mathematics capability, mathematics knowledge; confidence, self-belief and attitude (see Appendix I). These constructs emerged from the two literature reviews that were conducted and presented in Chapter 3 of this document. The constructs fell under two broad clusters, scaffolding and cognitive. Figure 5.4 shows the clusters and their constructs that were used to represent the interview responses of the11 IT students. The report is structured and uses the research questions as headings.

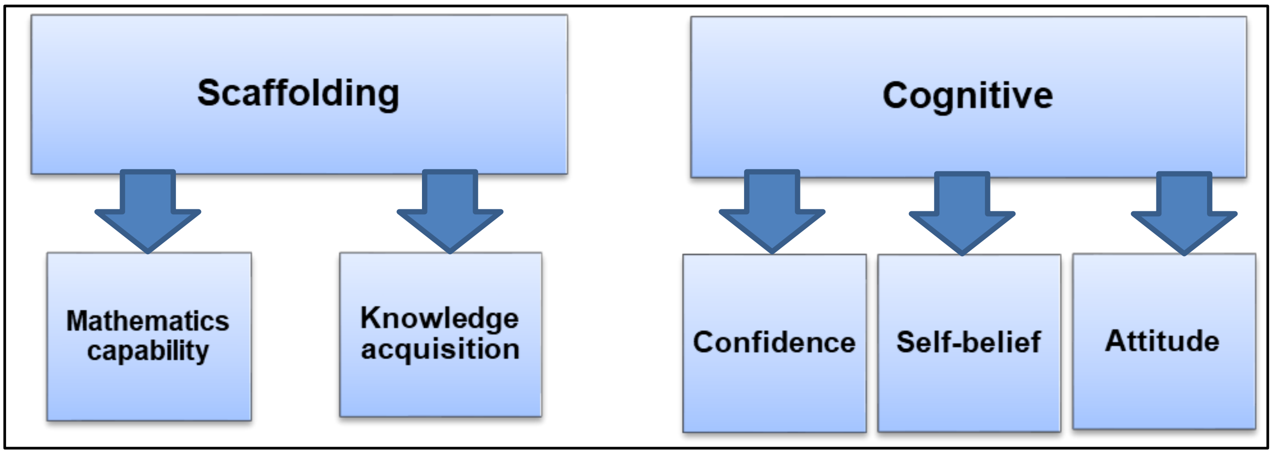


Figure 5.4: Emergent constructs

Qualitative data analysis

Interview responses gained from 11 purposefully selected IT students from the 2015 HCINCT programme were analysed to find answers to sub-question 4. The data analysis process is discussed in detail in Chapter 3 of this dissertation.

5.4.3 Phase 3: Consolidation

Amalgamation of mixed methods results

Under the amalgamation of both (mixed) methods results, the research questions are discussed in relation to the two conducted literature reviews to determine if the findings of this study are consistent with the literature reviewed. A tentative answer is offered for each research question and the final answers to the research questions are presented in Chapter 6. The amalgamation of both mixed methods results are discussed after phase 2 findings have been presenting and this happens towards the end of this chapter. The following section presents the quantitative findings.

5.5 FINDINGS

This section addresses one main and four sub-questions.

5.5.1 Main research question

The main research question inquired: What is the effect of the intervention programme on the mathematical knowledge of IT students upon entry into the HCINCT programme? To find answers to this research question, hypotheses were constructed based on historical data. The null hypothesis (H_o) claims that there is no statistically significant difference between the groups' mean scores before and after the MCI (the treatment). The alternative hypothesis (H_a) claims that there is a statistically significant difference between the groups' mean scores before and after the MCI. The objective for asking this research question was to determine the effectiveness of the MCI on the mathematical knowledge of IT students on exit. The baseline against which the hypotheses were tested was a 50 minimum score, which is the minimum score required to pass any course offered at the UoT where this study was conducted. The minimum 50 score is stated in the General Handbook: Academic and Student Rules and Regulations of the UoT where this study was conducted.

Choosing a statistical tool for data analysis

Numerical data obtained from the pre-test and post-test scores were continuous ratio scaled data. The data were collected at different intervals with the same students in the experimental group (E1) and the control group (C1). The IBM SPSS output that was used by the researcher to interpret the data for the main research question and sub-question 1 is attached at the end of the discussion regarding sub-question 1. The IBM SPSS data outputs used to analyze sub-questions 2, 3, 4 and 5 are attached at the end of the discussion on each sub-question. The guidelines of Raveendran, Gitanjal and Manikandan (2014) are presented in Table 5.4. These guidelines informed the choice of suitable statistical tests for the quantitative research questions.

Table 5.4: Choosing a statistical test (Raveendran, Gitanjal and Manikandan, 2014)

Data Type	**Comparison**				**Association** (Relationship between two variables)	**Regression** (Predicting regression)
	2 data sets		>2 data sets			
	Paired	Unpaired	Paired	Unpaired		
Normal Distribution (Mean)	Paired t-test	Unpaired t-test	Repeated measures ANOVA	One-way ANOVA	Pearson Correlation	Linear Regression
Non-Distribution (Median)	Wilcoxon Signed Rank	Wilcoxon Rank Sum test Mann Whitney ‘U’ test	Friedman test	Kruskal-Wallis	Spearman’s Rank Correlation	Non-parametric Regression
Dichotomous data	McNewmar test	Chi-Square test Fischer Extract test	Cochrane Q	Chi-Square test	Contingency Coefficient	Logistic Regression

Using the guidelines laid out in Table 5.4, the nature of the null hypotheses and the collected data for the main research question befitted data analysis with a paired sample t-test method. Data were checked to determine if they met assumptions for analysis using the paired samples t-test. The level of significance chosen was .05, which is the most common level of significance used by researchers (Field, 2018). The critical values used were the t-test values gained from the IBM SPSS outputs. The reason for using the t-values was to compare the means of the two groups in order to determine whether or not there was a significant difference between them. The Solomon 1949 guidelines were used by the researcher to assign the students' randomly into groups.

The analysis was performed using the following four groups:

1. Experimental Group 1 (E1);
2. Control Group 1 (C1);
3. Experimental Group 2 (E2); and
4. Control Group 2 (C2).

E1 (n=37) was given a pre-test followed by the MCI (the treatment). A post-test was thereafter administered to determine whether or not the intervention had a significant effect on the students' performances.

C1 (n=37) was given a pre-test and a post-test without the MCI (the treatment).

E2 (n=37) was not given a pre-test but received the MCI (the treatment) and a post-test.

C2 (n=36) received the post-test only.

Total subjects = 147

Checking paired t-test assumptions

In a paired samples t-test, the dependant variable must be measured on a continuous scale; the data is measured at the interval or ratio level (Bluman, 2015) The students' assessment scores were produced using the same assessment tool and the instrument used produced continuous data represented through the students' assessment scores. In addition, one needs dependent observations (Field, 2018). In this instance, the students' pre-test scores were matched with the post-test scores so for each participant, there were two scores. The paired t-test also assumes that the participants were randomly sampled from the population; this assumption was also met. The other assumption deals with the differences between the dependent variables and these differences need to be approximately normally distributed. The differences must not contain any significant outliers (Raveendran, Gitanjal and Manikandan, 2014).

Figure 5.5 demonstrates the absence of outliers.

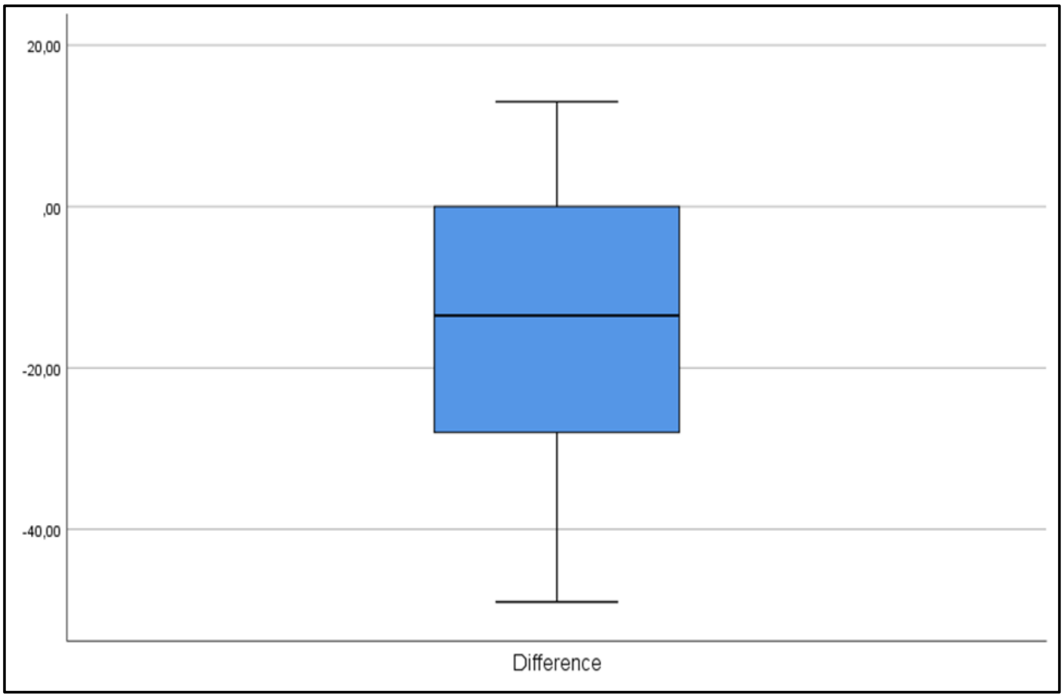


Figure 5.5: Differences

The box plot illustrated in Figure 5.5 shows that there are no outliers in the data distribution. Based on the information obtained from the IT students' pre-test and post-test scores, the data meets the samples' paired t-test assumptions. The researcher assessed the normality of the scores for groups E1 and C1, the two groups that were administered a pre-test and a post-test. Since each group had less than 50 subjects, the Shapiro-Wilk test was considered to be the best test for normality (Shapiro and Wilk, 1965; Shapiro, Wilks and Chen, 1968; Howell, 2013).

Even though the Kolmogorov-Smirnov test accommodates samples with N=50 and more (Kolmogorov, 1933; Smirnov, 1933; Birnbaum, 1952; Lilliefors, 1967; Riffenburgh, 2012). However, the Shapiro-Wilk method is more robust and is used by most researchers, especially when the sample size is less than 50 (Razali and Wah, 2011). The IBM SPSS output used in these analyzes is presented in the section that follows after Figure 5.6 within sub-section 5.5.2. The results of the analyses indicated that the variables were normally distributed. This is demonstrated in Table 5.5.

Table 5.5: Pre-test and post-test normality

	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
E1 Pre-test	.980	37	.74
E1 Post-test	.954	37	.13
C1 Pre-test	.940	37	.05
C1 Post-test	.961	36	.22

The researcher assessed the descriptive statistics of groups E1 and C1. There was a noticeable difference between the mean values for E1 scores on the pre-test ($\overline{X}$ =41.27, SD=5.11) and the post-test ($\overline{X}$=71.46, SD=12.06). The mean for the C1 pre-test ($\overline{X}$=39.62, SD=6.3) was not noticeably different from the C1 post-test ($\overline{X}$=39.16, SD=5.0). The researcher further assessed the differences between these two sample means using a paired samples t-test to assess statistically significant differences between the scores of the pre-test and the post-test for groups E1 and C1. The results of the two paired samples t-tests indicated that there were significant differences between the scores of the E1 pre-test ($\bar{X}$=41.27, SD=5.11) and the post-test measures ($\bar{X}$=71.46, SD=12.06): $t(36)=-22.936$, $p<.001$ (two-tailed). The mean increase in scores was -30.189 with a 95% confidence interval ranging from -32.859 to -27.520. The eta squared statistic (.94) indicated a large effect size. For Group C1, there were no significant differences between the scores of the pre-test ($\bar{X}$=39.62, SD=6.3) and the post-test measures ($\bar{X}$=39.16, SD=5.0): $t(36)=.723$, $p>.05$. Thus, the researcher reached the conclusion that there are significant differences between the pre-test and post-test scores for Group E1.

Figure 5.6 demonstrates the mean mathematical knowledge scores for the pre-test and the post-test administered to students in Group E1 and indicates the differences in the student assessment scores of this group.

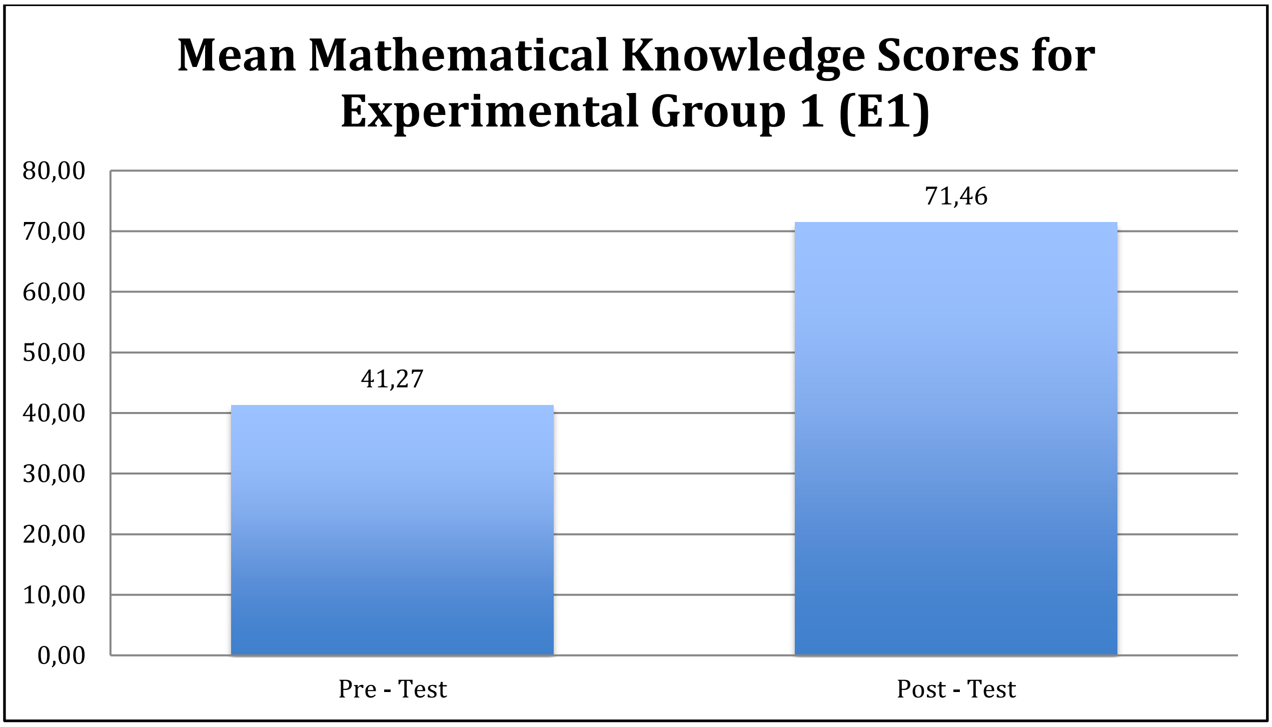


Figure 5.6: HCINCT 2015 IT students' mathematical knowledge on average

The post-test scores of the IT students in Group E1 demonstrate an increase in the students' mathematical knowledge from that on entry.

5.5.2 Sub-question 1

Sub-question 1 inquired: Are the post-test scores of all groups significantly statistically different? The null hypothesis (H_o) claimed that the means of each group are the same. The alternative hypothesis (H_a) claimed that there is a mean difference between at least two groups. The objective for this research question was to determine whether or not the means of the post-test scores of the four groups were significantly different. Following from the data analysis conducted for the main research question, a further analysis was performed to determine whether or not the means of the four post-test groups were significantly different. A one-way (between groups) ANOVA was performed. There was a significant effect between the mathematical knowledge scores of the post-tests of the four groups, E1, C1, E2 and C2 ($F(3,143) = 160.108$, $p < .001$). Post hoc comparisons using the Tukey HSD test indicated that the mean ($\bar{X}$) score for Group E1 ($\bar{X}$=71.46, SD=12.06) was significantly different from Group C1 ($\bar{X}$=39.16, SD=4.96) and Group C2 ($\bar{X}$=38.96, SD=4.67).

However, Group E1 did not significantly differ from Group E2. Group E2 ($\bar{X}$=72.59, SD=11.84) was significantly different from Group C1 ($\bar{X}$=39.16, SD=4.96) and Group C2 ($\bar{X}$=38.96, SD=4.67). The two control groups, C1 and C2, did not differ from one another. The Levene's test was significant. Therefore, the data for the ANOVA violated the normal distribution assumption. However, due to the fact that there were four different groups with very different means and observations, the ANOVA test results are used for the discussion.

The students' post-test assessment scores violated the normal distribution assumption because the scores were normally distributed between the 60s and the 80s only. A pictorial distribution of the students' post-test scores followed a binominal distribution. Since there was a question of normality for the C1 pre-test group determined by the Shapiro-Wilk test ($p < .05$), a Kruskal-Wallis test was conducted that compared the results of the post-test for all four groups. A significant result was found ($H(3)=109.848$, $p < .001$), indicating that at least two of the groups differed from each other (see summary table below).

Follow-up pairwise comparisons indicated results identical to the ANOVA. Group E1 was significantly different from Group C1 ($H(1)=54.831$, $p < .001$) and Group C2 ($H(1)=54.155$, $p < .001$). However, Group E1 did not significantly differ from Group E2 ($H(1)=0.288$, $p > .05$). Group E2 was significantly different from Group C1 ($H(1)=54.928$, $p < .001$) and Group C2 ($H(1)=54.173$, $p < .001$). The two control groups, C1 and C2, did not differ from each other ($H(1)=0.040$, $p > .05$).

Figure 5.7 displays the hypothesis test summary.

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of post-test is the same across the categories	Independent-Samples Kruskal-Wallis Test	0.000	Reject the null hypothesis
Asymptotic significances are displayed. The significance level is 0.05.				

Figure 5.7: Hypothesis test summary

The post-test scores showed that the intervention increased the mathematical knowledge of most 2015 HCINCT students. However, for a small group of students, the mathematical knowledge either decreased or remained the same. The IBM SPSS output used in the data analysis and the data presentation for the main research question and sub-question 1 are attached below.

IBM SPSS output: Main research question and sub-question 1 data analysis

Table 5.6: T-Tests

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
E1Pre-test	.072	37	.200*	.980	37	.736
E1Post-test	.158	37	.021	.954	37	.128
C1Pre-test	.150	37	.036	.940	37	.046
C1Post-test	.163	37	.015	.961	37	.219
*. This is a lower bound of the true significance.						

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	E1Pre-test	41.27	37	5.113	.841
	E1Post-test	71.46	37	12.059	1.983

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	E1Pre-test and E1Post-test	37	.871	.000

Paired Samples Test

	Paired Differences			
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference
				Lower
Pair 1 E1Pre-test - E1Post-test	-30.189	8.006	1.316	-32.859

Paired Samples Test

		Paired Differences			
		95% Confidence Interval of the Difference	t	df	Sig. (2-tailed)
		Upper			
Pair 1	E1Pre-test - E1Post-test	-27.520	-22.936	36	.000

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	C1Pre-test	39.62	37	6.304	1.036
	C1Post-test	39.16	37	4.958	.815

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	C1Pre-test and C1Post-test	37	.790	.000

Paired Samples Test

		Paired Differences			
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference
					Lower
Pair 1	C1Pre-test - C1Post-test	.459	3.863	.635	-.828

Paired Samples Test

		Paired Differences			
		95% Confidence Interval of the Difference	t	df	Sig. (2-tailed)
		Upper			
Pair 1	C1Pre-test - C1Post-test	1.747	.723	36	.474

Table 5.7: One-way ANOVA

Descriptives

Post-test

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.
					Lower Bound	Upper Bound	
1	37	71.46	12.059	1.983	67.44	75.48	50
2	37	39.16	4.958	.815	37.51	40.82	30
3	37	72.59	11.840	1.947	68.65	76.54	53
4	36	38.86	4.673	.779	37.28	40.44	30
Total	147	55.63	18.874	1.557	52.56	58.71	30

Descriptives	
Post-test	
	Maximum
1	97
2	50
3	93
4	48
Total	97

Test of Homogeneity of Variances			
Post-test			
Levene Statistic	df1	df2	Sig.
18.025	3	143	.000

ANOVA

Post-test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	40076.723	3	13358.908	160.108	.000
Within Groups	11931.441	143	83.437		
Total	52008.163	146			

Table 5.8: Post Hoc Tests

Multiple Comparisons

Dependent Variable: Post-test

Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	32.297*	2.124	.000	26.78	37.82
	3	-1.135	2.124	.951	-6.66	4.39
	4	32.598*	2.138	.000	27.04	38.16
2	1	-32.297*	2.124	.000	-37.82	-26.78
	3	-33.432*	2.124	.000	-38.95	-27.91
	4	.301	2.138	.999	-5.26	5.86
3	1	1.135	2.124	.951	-4.39	6.66
	2	33.432*	2.124	.000	27.91	38.95
	4	33.733*	2.138	.000	28.17	39.29
4	1	-32.598*	2.138	.000	-38.16	-27.04
	2	-.301	2.138	.999	-5.86	5.26
	3	-33.733*	2.138	.000	-39.29	-28.17

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Post-test

Tukey HSD[a,b]

Group	N	Subset for alpha = 0.05	
		1	2
4	36	38.86	
2	37	39.16	
1	37		71.46
3	37		72.59
Sig.		.999	.951

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 36.745

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table 5.9: NPar Tests

Notes

Output Created		07-JAN-2019 14:45:40
Comments		
Input	Data	
	Active Dataset	DataSet1
	Filter	Group = 3 or Group = 4 (FILTER)
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	73
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each test are based on all cases with valid data for the variable(s) used in that test.
Syntax		NPAR TESTS /K-W=PostTest BY Group(3 4) /STATISTICS DESCRIPTIVES /MISSING ANALYSIS.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.08
	Number of Cases Allowed[a]	224694

a. Based on availability of workspace memory.

Descriptive Statistics

	N	Mean	Std. Deviation	Min	Max
Post-test	73	55.96	19.212	30	93
Group	73	3.49	.503	3	4

Table 5.10: Kruskal-Wallis Test

Ranks

	Group	N	Mean Rank
Post-test	3	37	55.00
	4	36	18.50
	Total	73	

Test Statistics[a,b]

	Post-Test
Chi-Square	54.173
df	1
Asymp. Sig.	.000

a. Kruskal-Wallis Test

b. Grouping Variable: Group

The statistical data presented above were used to support the null hypothesis for the main research question and sub-question 1. The IBM SPSS output for sub-question 2 and sub-question 3 are attached at the end of the data analysis for sub-question 3.

5.5.3 Sub-question 2

Sub-question 2 inquired: What evidence do we have to suggest that the sample came from a population for which the mean score was 50? The null hypothesis (H_o) claimed that there is no statistically significant difference between the mean score of the UoT students and the mean score of the HCINCT 2015 students. The alternative hypothesis (H_a) stated that there is a statistically significant difference between the mean score of the UoT students and the mean score of the HCINCT 2015 students. The research objective for sub-question 2 was to establish if the sample mean score in the HCINCT students' final-year assessment scores is a true parameter representing the IT students' mean score in 2015.

The UoT where this study was conducted requires students to obtain a minimum score of 50 to pass any of its courses. In addition, to pass the HCINCT programme and obtain certification, the students in the HCINCT programme are expected to pass all their courses with an overall mean score of 50. Data were numerical and they were measured at the ratio level. The guidelines for choosing a statistical analysis tool indicated were again followed (Raveendran, Gitanjal and Manikandan, 2014). At the end of the HCINCT programme, 122 students sat the final-year examinations. Twenty-five IT students had dropped the HCINCT programme between June and October 2015. The significant level used was 0.05 (Bluman, 2010; Bluman, 2015).

To test the null hypothesis, the students' HCINCT final-year assessment scores were used. The final-year mean scores were derived from the students' overall scores for all the 11 courses offered in the HCINCT programme. Therefore, the population mean score of 50 was used as a baseline to test the null hypothesis. The students' assessment results were graded on a scale of A to F. The type of experimental manipulation that was found to be appropriate for analysing the students' final-year assessment scores was the one sample t-test. The aim for conducting the one sample t-test was to determine if the intervention increased or decreased the students' mean score on exit.

Thus far, the discussion above regarding sub-question 1 revealed that some 2015 HCINCT students may have obtained an increase in mathematical knowledge. Some students' assessment scores raised the question of whether or not the MCI of 2015 enhanced the mathematical knowledge of IT students upon exit from the HCINCT programme. Hence, the researcher constructed this research question that asked:

What evidence do we have to suggest that the sample came from a population such that the mean score was 50? The objective for asking this research question was to establish if the sample mean score in HCINCT is a true parameter that represents the IT students' population mean score in 2015. Table 5.11 shows the South African grading scale that is followed by UoTs when grading students' results (https://www.classbase.com/countries/South-Africa/Grading-System).

Table 5.11: Grading scale and distribution of students' assessment scores

Grade	Division	Percentage
A	First class	75–100
B	Second class division one	70–74
C	Second class division two	60–69
D	Third class	50–59
Fail		0–49

Table 5.11 illustrates the scoring system that is used for grading students' scores at the UoT where this study was conducted. This grading scale allocates alpha variables to numerical variables (Bluman, 2010; Bluman, 2015) and one should not skew output values. Field, (2018) suggests that the type of data determines the type of statistical

tool used for analysis. Perhaps the one sample t-test demonstrates certain requirements. Field, (2018) suggests checking for four violations to assumptions when one intends using the one sample t-test as a statistical tool of data analysis. The assumptions for the one sample t-test are shown below. The measure represented by the students' final-year scores is measured using t-scores. The population mean score is 50. Sub-question 2 asked: What evidence do we have to suggest that the sample came from a population for which the mean score was 50? The students' assessment scores comprised the dependent variable.

Checking for one sample-test assumptions

The assumptions for conducting an analysis through the one sample t-test require the values to be independent and the assumptions represent independent observations. The dependent variable must be recorded as interval or ratio-scaled data. The dependent variable should not have outliers (field). The dependent variable should be normally distributed (see IBM SPSS output). The researcher decided in advance that this study would be conducted using the Shapiro-Wilk test for data interpretation.

The Shapiro-Wilk test was chosen because it is commonly used by most researchers (Shapiro and Wilk, 1965; Razali and Wah, 2011). There were no extreme values in the data ranges. The Shapiro-Wilk p-value of 0.105 value was greater than 0.05. The assumption is that the results of this test indicated that the data were normally distributed. The skewness and kurtosis values were used to evaluate if the data met the assumptions for data analysis using the one sample t-test.

One guideline for assessing a normal distribution using skewness is that the absolute value for skewness cannot exceed .8 (Doane and Steward, 2011). The data qualified for normality since the skewness did not exceed .8. Another guideline for evaluating if data meet the kurtosis normality assumption is that the absolute value can exceed 2 (Bryman and Cramer, 2011). The data of the current study passed all the assumptions for data analysis using the one sample t-test. The IBM SPSS data output for sub-question 2 is presented below. Figure 5.8 illustrates the histogram used to determine if the data were normally distributed.

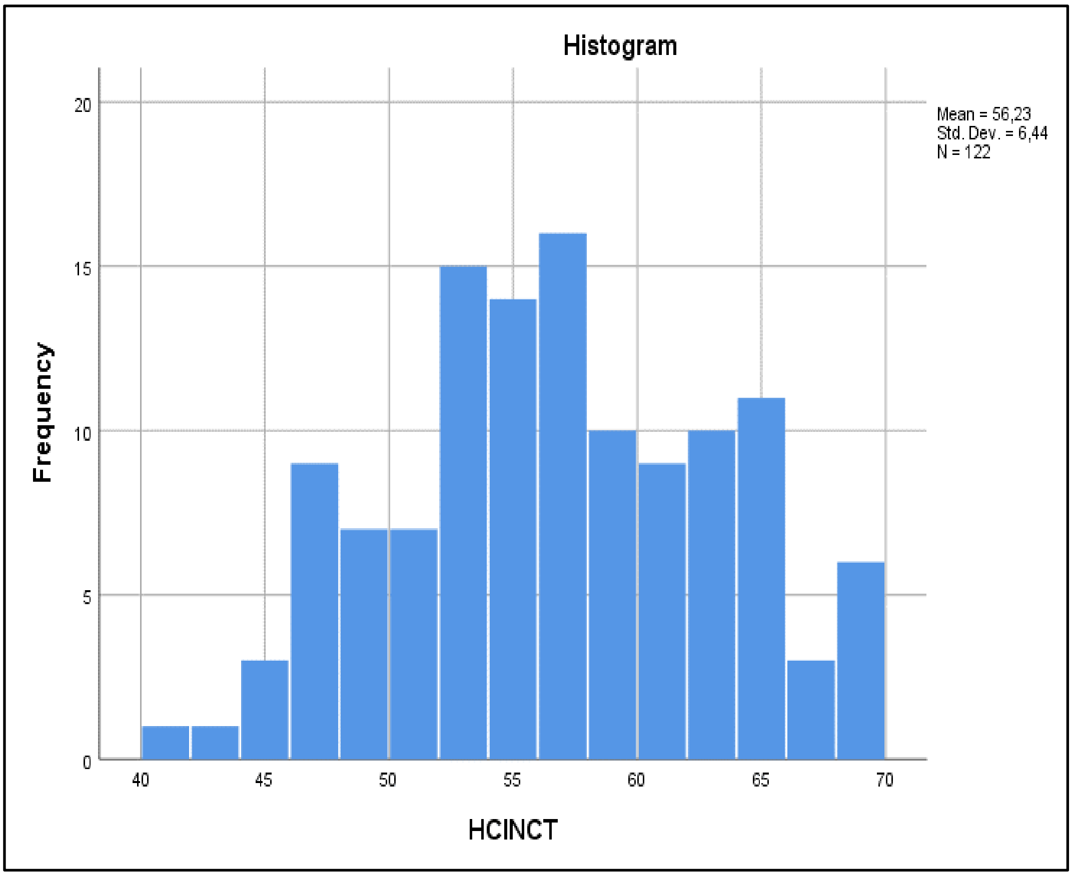


Figure 5.8: Data distribution

The data represented in Figure 5.8 meet the normal distribution assumption because there is a bell curve. Although, the histogram is not perfect, a bell curve can be seen.

A boxplot (Figure 5.9) was used to test if the data met the assumptions for outliers.

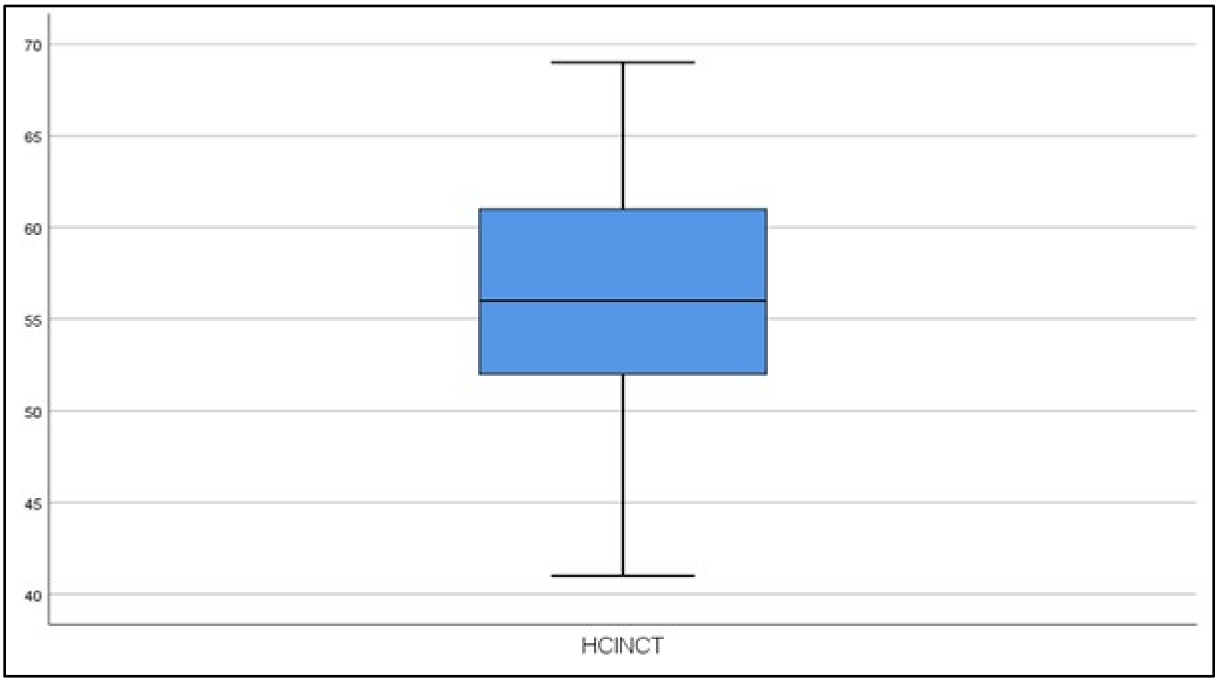


Figure 5.9: Testing for outliers

The boxplot displayed in Figure 5.9 demonstrates that no values were plotted outside the whiskers. It was thus determined that the data had no outliers.

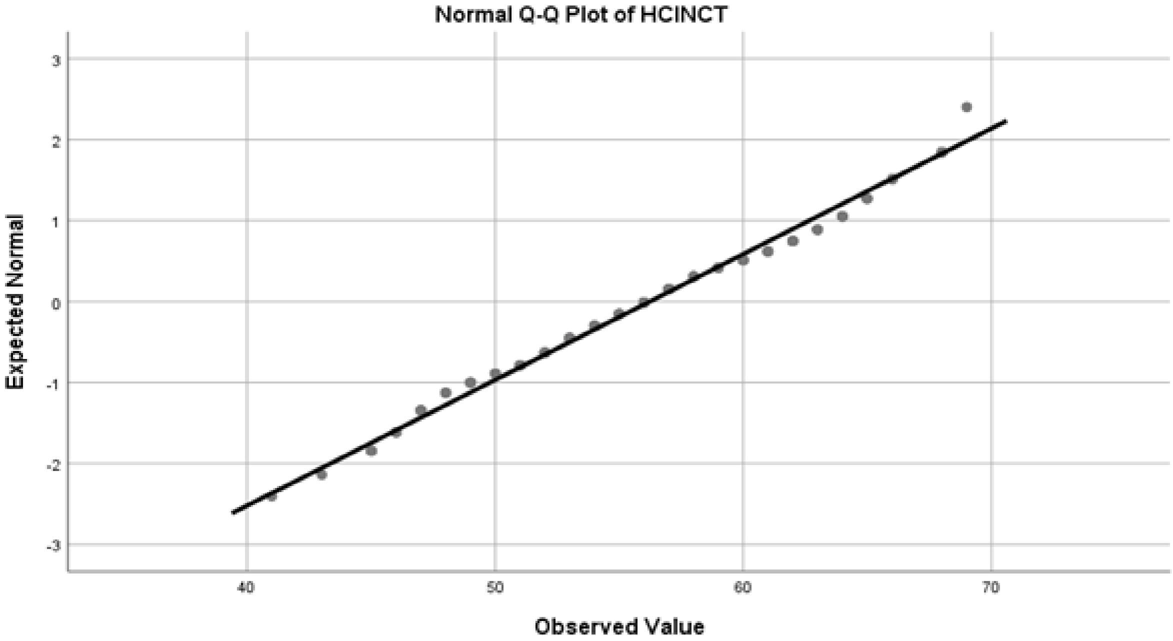


Figure 5.10: Data distribution

The pictorial data display in Figure 5.10 indicates that the data did not have extreme values. Based on the skewness and kurtosis values, the Shapiro-Wilk p-value, the histogram, the whisker plot and the Q-Q plot, the data met all the one sample t-test assumptions. Sub-question 2 data analysis was carried out after the data qualified for analysis through a sample t-test. A p-value of 0.00 means that there is a 0.000% chance that values are observed through random error alone (Wright, 2003 and Gujarati and Porter, 2013). Since the p-value was less than .05, the null hypothesis that claims that there is no statistically significant difference between the UoT mean score and the HCINCT mean score is rejected.

The IBM SPSS data output below was used to test the null hypothesis of sub-question 2. See first table below.

Table 5.12: Test of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
HCINCT	.061	122	.200*	.982	122	.105

*** This is a lower bound of the true significance.**

a. Lilliefors Significance Correction

Descriptives

	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
HCINCT	122	100.0%	0	0.0%	122	100.0%

Descriptives			Statistic	Std. Error
HCINCT	**Mean**		56.23	.583
	95% Confidence Interval for Mean	Lower Bound	55.08	
		Upper Bound	57.38	
	5% Trimmed Mean		56.24	
	Median		56.00	
	Variance		41.468	
	Std. Deviation		6.440	
	Minimum		41	
	Maximum		69	
	Range		28	
	Interquartile Range		9.25	
	Skewness		-.010	.219
	Kurtosis		-.733	.435

Extreme Values			Case Number	Value
HCINCT	Highest	1	101	69
		2	2	68
		3	16	68
		4	103	68
		5	113	68[a]
	Lowest	1	66	41
		2	21	43
		3	121	45
		4	56	45
		5	9	45

a. Only a partial list of cases with the value 68 is shown in the table of upper extremes.

Table 5.13: One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
HCINCT	122	56.23	6.440	.583

	Test Value = 50					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
HCINCT	10.685	121	.000	6.230	5.08	7.38

In the 2015 HCINCT programme, 31% of the 122 students obtained a 65 aggregate score and could progress to the IT diploma. The remaining 69% students attained a 50 aggregate score for their 11 subjects. Since the condition for HCINCT certification is that all 11 subjects in the HCINCT programme are passed with a minimum score of 50, the majority of the students could not progress to the IT diploma.

5.5.4 Sub-question 3

The research sub-question 3 inquired: Is there a statistically significant difference between the HCINCT 2016 mean score and the HCINCT 2015 mean score on exit? The null hypothesis (H_o) claimed that there was no statistically significant difference between the HCINCT 2016 mean score and the HCINCT 2015 mean score on exit. The alternative hypothesis (H_o) claimed that there was a statistically significant difference between the HCINCT 2016 mean score and the HCINCT 2015 mean score on exit. The null hypothesis was created using students' historical data.

To test the null hypothesis, the final-year assessment scores for the two groups were evaluated. At the end of the 2016 academic year, n=174 students took the final-year examination. The study was replicated with the HCINCT 2016 students. The HCINCT programme had been ceded to four TVET colleges in 2016. This was in line with a government mandate that urged universities to work with TVET colleges in an effort to provide access to university studies for people who came from historically disadvantaged backgrounds (Alexander, 2013; The presidency, 2015).

The researcher was responsible for coordinating the QT course content and lectured QT at the four colleges once a month. Four full-time lecturers taught QT and were employed by the colleges. The UoT sponsored the TVET colleges financially and assisted with administrative resources and quality management of the HCINCT programme. Students volunteered to participate in the study at the beginning of their academic year once the researcher had informed them about the investigation. The statistics of both student groups that were used for data analysis are presented below.

Table 5.14: Group statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Scores	HCINCT 2016	174	64.26	14.228	1.079
	HCINCT 2015	122	63.45	8.839	.800

The standard deviations and the standard error mean values for the two groups were different. This was due to the differences in the number of students in each group (sample size) and the actual scores obtained by the students. Both the standard deviation and the sample size affected the standard error in each group. However, by considering the mean scores of the two student groups, the null hypothesis that claims that there is no statistically significant difference between the mean scores of the

HCINCT 2015 students and the mean score of the HCINCT 2016 student on exit is rejected.

5.5.5 Sub-question 4 – responses of students

Sub-question 4 inquired: Under which circumstances did the students results improve? The objective for asking this research question was to determine the criteria for successfully improving the students' results. To find answers to this research question, interview responses gained from 11 purposefully selected IT students were analysed. The qualitative research questions posed to the students are used as headings to present the data analysis findings.

1. How has the MCI prepared you for the IT programming courses in the HCINCT programme?

Some students said that the MCI had an effect on their IT programming courses because it scaffolded their mathematics capabilities on which their IT programming skills were built. One student stated that for him, binary arithmetic helped his understanding of IT networks. Another student felt that time was spent on numeracy content that had little relevance to his immediate quantitative techniques needs. One participant responded that he would have appreciated the MCI if more time was spent on learning the mathematics needed for IT programming, while another complained that he wanted more challenging mathematical content. Another student stated that the MCI required extra time from her limited study time, but the intervention had made a significant improvement in her first-year university studies at the UoT.

2. What was the effect of the QT class tutorials on your mathematical skills?

One student stated:

> *The MCI taught me that I had the mathematical capability to do well from my high school education. Now I realised that I just had to apply myself very hard until I got a breakthrough in quantitative techniques (QT).*

Some students expressed that their mathematical knowledge increased, allowing them to scaffold their IT programming skills with their newly acquired numerical skills. One student declared that the QT class tutorials were a safe place where he felt that he could practise his quantitative skills. Another student maintained that through the QT class tutorials, he had developed friendships with other students in the HCINCT programme who helped him develop his numerical skills. In a separate interview response, a student declared that in the beginning, she hated the QT class tutorials because she felt it exposed the weaknesses in her numerical skills.

However, once she realised that nobody was concerned whether her numerical skills were good or bad and that she was not the only student who was struggling, she applied herself and her mathematical knowledge increased. One participant said he noticed that all the students who had volunteered for the MCI had one common goal and that was to enhance their mathematical capability and this helped him. Another student claimed that having a common goal with other students gave him the confidence to approach the lecturer and other students who had volunteered to act as tutors for support.

3. How were your experiences with the MCI?

Most students who underwent the MCI felt that the programme was worthwhile and that it built their confidence not only in numbers but also in other subjects. Some students asserted that this confidence influenced their overall first-year university experience. One student felt that the MCI contained some challenging content, but most of the content was boring for him since he felt that his numerical skills were more advanced than those of his classmates. Another participant said that the content of the QT class tutorials was excessive and the time allocated to cover the content was insufficient. One student claimed that he struggled with the QT class tutorials and felt that his skills never improved because he had no time to practise at home.

One of the students stated:

> *I think, well, I question things; I do not accept something without using my deductive reasoning skills to analyze every bit of information and come out with different perspectives on an issue.*

The student said that he learnt these skills through the MCI. Nowadays, he applies these newly acquired skills to everything he does and they have worked for him thus far. The same student announced that the MCI restored his confidence in working with numbers, increased his cognitive skills and boosted his self-confidence. Another student responded similarly to the question:

QT class tutorials were a wonderful experience for me and it made me realize that there are people out there who have my interest at heart and that I only need to read for my own understanding.

Another student lamented:

> *I struggled with class non-attendance due to train problems. I missed tutorials. Sometimes when I was late, I would find out that people had moved on, so I had to do catch up. Just after class, I would approach my classmates and ask for help. My classmates were helpful.*

The remaining students' comments during the one-on-one interviews suggested that they were confident in their mathematical abilities based on what they were taught and their matric results.

4. What comprises good mathematical capabilities for you?

Most students maintained that good mathematical capabilities meant having sufficient mathematical knowledge to be competent in their IT programming programmes. One student said that good mathematical capabilities meant having enough knowledge to understand algebraic algorithms and the binary arithmetic needed in basic IT programming and feeling competent enough to learn and understand IT programming courses in the HCINCT programme.

5. Under which circumstances did your mathematical capabilities improve?

One student claimed that her mathematics capabilities increased when she started practising on her own. Some students said that their mathematics skills increased when they began to collaborate with other students. One participant revealed that a student in his group started coaching other students and that was when his mathematical knowledge increased. Some students disclosed that their mathematical skills improved when they began asking for more exercises from the lecturer. Another student believed that the one-on-one tutorials with the lecturer helped her and her colleagues improve their mathematical capability.

6. How were your numerical skills developed during your primary school education?

One student replied, "In primary school, mathematics was easy; I always got distinctions." Another student confessed, "I was one of the worst students in mathematics at primary school. I think that high school partially prepared me for first-year university education." By contrast, one student said that he was good at mathematics in primary school and felt that he had acquired solid foundational mathematical skills. However, the same student stated that he lost focus at high school because he felt that some mathematics teachers were too advanced for him. He attributed his achievements to repeating all class exercises at home every time he had to prepare for the examinations because the teachers used the same questions year after year.

One student responded, “My mother and I lived in different provinces. I have been to about ten different schools during my schooling life.” Because of this, this participant never settled in one school long enough for the teacher to notice that he was weak in mathematics. Thus, he was never good at mathematics in primary school. The same student added that he learnt very early in his primary schooling that he had to be a nice child who the mathematics teacher liked; the teacher would take a liking to him and send him on errands during mathematics class lessons. In each new school, he used this strategy and it worked for him.

Another student replied to this question: “My primary school mathematics was good. I just never got to practice the things I learnt in primary school out of the school classroom and I forgot them.” This student also felt that his primary school mathematics prepared him for the mathematics education after his primary and secondary school years. Despite this preparedness, he stated that his high school years did not prepare him for his first-year IT studies. He added that the mathematics he studied through the QT tutorial classes was different. Apparently, at high school, the lower grades covered parabola basics, but they never focused on the basic elements. He said high school mathematics was focused on complex equations and thus, he had not known some of the foundational arithmetic rules that he learnt in the MCI programme.

The participant continued:

> *I was a top student in all my primary school mathematics. However, I lost interest in high school mathematics, but I was well prepared for the matriculation examinations; I studied on my own and followed the Maths book.*

He said that he received a good symbol in pure mathematics. He stated that he matriculated in 2012, but he had been out of the country for a year. On his return to South Africa in 2014, he applied for IT studies, but the IT programme that he applied for was not his first choice and he was not accepted into an IT programming course. He applied again in 2015 and made IT programming his first choice. His application was late but fortunately, he was accepted onto the HCINCT programme.

Each of the 11 interview respondents were asked to comment on whether or not they thought the mathematics that they had learnt in primary school enabled them to scaffold their IT-related courses with their IT knowledge during their first-year of university studies. One student mentioned that she had learnt to memorise arithmetic laws, but she could not rationalise or contextualise mathematical problems. Another student declared, “My primary school mathematics was wonderful. I was in Johannesburg and I went to a semi-private school.” This participant stated that he enjoyed foundational arithmetic.

He elaborated that his school had provided learners with support through tutors and that in Johannesburg, both teachers and tutors helped all learners who were struggling with operational mathematics. He explained that he never struggled with mathematics at that time because he had many people available to help him and he was able to achieve grades ranging between 75% and 80+% for mathematics. This mathematics support continued until he was in Grade 5.

However, he subsequently relocated to Cape Town with his mother and attended Grade 6 at a public school in the Northern suburbs of Cape Town. The student mentioned that there were many changes that he encountered in his new location. Among these was the fact that he was struggling with mathematics. He no longer had tutors to help him as he had while attending school in Johannesburg. In addition, fulfilling other basic needs was a struggle and investing money in mathematics tutors was the least of his mother’s worries. The student stated that by Grade 7, he hated mathematics. He also noticed that the type of mathematics being taught in Cape Town was more difficult than the type being taught in Johannesburg and the teaching style was different.

Teachers in the Cape simply presented the students with mathematics problems and left them to struggle on their own. This participant felt that teachers did not help students at all; they simply pushed the student towards mathematics. The student said that the way that mathematics is taught is important but in his school, the teachers drove him away from mathematics. He elaborated that when he was in Grade 8, he received help from senior students who were doing pure mathematics in Grade 10. The student said that the more help he got from these Grade 10 students, the easier mathematics became for him. He said that before he knew it, he liked mathematics. Another student said that although he struggled with mathematics at school, he took pure mathematics in Grade 10 because the more he struggled with mathematics, the more fun he had.

Finally, the sums started adding up correctly for him and he felt a real sense of achievement. When he joined the university, he mentioned that he was not strong with numbers and he saw the effort that the lecturer was putting into the QT class tutorials for the students. Once again, the fun aspect of learning while playing with numbers made him want to do better. He kept working harder and harder and soon he was a top student in his QT class. He said he started helping his friends and they also began to enjoy the subject and do well in other subjects.

7. How has your high school mathematics education contributed to your mathematical skills?

Some students said that they understood important arithmetic laws but had lost that knowledge on transit from high school to their first-year university studies. One student stated that her high school Grade 8 mathematics was very easy. She explained that she had received 95% for her mathematics subject at the end of Grade 8 and with this mark; she was the highest achiever in her class of 41 pupils. Then she moved to Grade 9. The Grade 9 mathematics teacher clustered all the top achievers from Grade 8 into one class. The student elaborated that from then on, she stopped enjoying mathematics because Grade 9 mathematics classes became very competitive.

According to this student, her high school mathematics teacher would draw up a list of the top 20 students in mathematics after every assessment. The student mentioned that her name never featured in any of these top achiever lists. This led to her losing interest in the subject of mathematics because the competition was too high and too vigorous and as a result, her mathematics scores went down. She said that it was due to demotivation that she stopped practising or studying mathematics as much as she had in the grades prior to Grade 9.

Thereafter, she became an average student, obtaining 70% in pure mathematics. She passed her matriculation in this range and entered the HCINCT foundation programme by default because she was a late registration student. She was very grateful that she was accepted into the HCINCT programme. She said that the mathematics capability programme made her realise that in reality, she did not know mathematics; she knew how to practise problems from past examination papers and how to follow the teacher's examples in order to pass.

Another student admitted that he never knew how to do long division and fractions and the basic mathematics taught at primary school, which resulted in him doing mathematics literacy from Grade 10 to Grade 12. He passed mathematics literacy and came to study IT accidently. He said that he had applied for media studies without knowing that it fell under IT. He explained that he would not have applied for an IT course because he knew that he would have failed. He stated that he was not prepared for the MCI programme and was glad that he was placed in a group that did not get the treatment.

He also mentioned that at the end of the programme, he dropped the HCINCT programme and did not wait to take the final-year examinations. He said he is happy now because he applied and was accepted into a faculty that is well suited to him because no counting is involved. Another student replied to the same question as follows: "I had no solid background in mathematics. I passed matric by chance. I just went by through my high school not caring for anything." He expressed that at this time; he was a troubled teenager and fought a great deal at school.

However, he eventually realized that he could not continue behaving this way and began to attend school every day, doing what he was told through the remainder of his school career. And now, he is at university. He declared that he wants to better himself. He said that these days, he applies himself and this is what he has learnt through the MCI. This new way is working for him. The arguments raised by the students supported the literature reviewed on how students should use self-efficacy, self-belief and a positive attitude in taking responsibility for their own learning and acquiring mathematical knowledge that will in turn, increase their mathematical capability.

8. To what degree did your attitude towards acquiring mathematical knowledge help you?

Students said that they put in more time, worked in collaboration with other students and used all the resources that were provided for them by the UoT where this study was conducted.

9. How has high school mathematics education prepared you for your first-year university studies?

One of the students replied, “My high school was and still is one of the best schools that there is, in my personal opinion.” He said that high school prepared him well for the mathematical world and for the tertiary mathematics that he would encounter in reality. He elaborated that a retired senior mathematics teacher, previously the Head of the Mathematics Department for the country, taught him mathematics at high school. The student said that his mathematics teacher set matriculation examination papers for the country and that he was an excellent teacher.

The student added that once he entered the UoT where this study was conducted, he felt that the MCI content was an easy task for him. The student narrated that the ease of the MCI content was due to the thorough and in-depth mathematical learning that he obtained during his high school years. The student said that to give a more basic answer, he was very, very prepared for his first-year IT studies because “mam knows it was a breeze for me to study through the MCI programme”. He said that for him, the experience he gained through the MCI was amazing and that he had an amazing lecturer.

A follow-up question was posed to this student: If the MCI was so easy, why is it that you were one of the 95% of students who failed a third pre-test set at the level of South African Grade 6 content? The student replied,

To answer your second question, I think that there is something wrong with our education system to have so many students that failed Grade 6 mathematics. I also want mam to know that I was not serious in that first week of varsity and actually, it took me the whole first term to realise that I had to up my game. Another student said that his high school mathematics education prepared him for his tertiary education. He added that he thought students should continue with mathematics as part of their IT syllabus because they need mathematics to understand IT education.

Another student replied to the same question by saying that in high school, his mathematics class used to do many calculations on the board. Thereafter, the mathematics teacher would put the students in a secluded classroom and there, the students would solve problems for hours and hours. He said they would write formulae on the walls and follow them step by step. This student said that this prepared him for his UoT studies. When the follow-up question was asked enquiring why he was in the 95% of students who failed mathematics set at Grade 6 level, the student replied that this is because he did not have a calculator or formulae and did not know what to do without a formula because he had been taught to apply a formula to solve a mathematics problem.

5.5.6 Sub-question 4 – responses of IT domain experts

The principles laid down in the Delphi model were used to identify IT domain experts in the IT department where this investigation conducts (Lilja, Laakso and Palomäki , 2011) Nine IT domain experts volunteered to participate in the research. The eight constructs that emerged from the literature reviewing process outlined in chapter 2 were used as guidelines to create five interview questions. Informal, but planned, interviews were scheduled with individual experts. IT domain expert’s individual interviews took place over a few days. Epoché, or bracketing, was used to set aside own experiences as much as possible and to take a fresh perspective toward the investigation (Husserl, 1931; Husserl, 1970). The researcher held the concept of reflexivity during the story telling in this investigation where conscious bias, values and experiences of the researcher were not brought forth while mediating between different meanings in telling the story about the phenomenon under investigation (van Manen, 1990 ; Creswell, 2013). Experts' comments were recorded verbatim and anonymity was preserved. Permission was sought from experts in the IT department to publish their comments and permission was granted to the researcher by the IT experts in January 2015. Six themes mapped to the six interview questions (Appendix H) emerged as follows:

- Mathematics capabilities of first year IT students on entry at the UoT;
- Necessary steps for the enhancement of the students' mathematics capabilities;
- Noted shortfall in students' numerical skills upon entry into the UoT;
- Required numerical capabilities for study of IT programming courses;
- Experience of IT experts regarding students' numerical abilities; and
- Overall mathematical capabilities of 3rd and fourth years IT students at the UoT.

Mathematics capabilities of first year IT students on entry at the UoT

Some experts said that students that enter the University of Technology for the first time either have poor, limited and or irrelevant numerical skills. One expert stated that it is not only first year IT students that enter their University studies mathematically underprepared to begin their studies that expects them to have a certain level of mathematic capabilities upon which their IT programming skills could scaffold.

The expert mentioned that third year IT students do not understand operational mathematics/basic arithmetic and these are basic skills that he thinks are fundamental for the students to be successful in their IT programming courses. Another IT domain expert suggested that if students join the IT programme courses with good results in their matric exams they come into their studies with confidence in their ability to do well. He clarified that any university will demand that mathematics should be a prerequisite for Computer Science courses.

Necessary steps for the enhancement of the students' mathematics capabilities

One IT domain expert stated:

The majority of the students are not confident about their numerical skills.

One lecturer argued that first year students do not know how to acquire knowledge. He said that he found that the students come with no knowledge of using macros on Microsoft Excel and if students lack this basic prerequisite, it holds back their progress. He elaborated that his course requires the students to have intermediate level of Microsoft Excel skills, due to the fact that there is only one year to cover a lot of work and the pace is high.

This lecturer commented:

> *When 98% of the students in a course are struggling with the basics of Microsoft Excel, I find it impossible to lecturer the students a programming language that I have designed for the course.*

Noted shortfall in students' numerical skills upon entry into the UoT

Some IT domain experts suggested that if students join the IT programme courses with good results in their matric exams, they come into their studies with confidence in their ability to do well.

Required numerical capabilities for study of IT programming courses

One IT domain experts said that first year IT students do not need to have foundational arithmetic/operational mathematics to acquire IT knowledge. Another expert said that mathematics in a Computer Science programme is written in a variety of modules from first year to third year. He expressed that in Computer Science, there are algorithms for sorting techniques, where very difficult mathematics govern such algorithms like proving that an IF statement or a While looping hold true in a multi-processing environment. The expert argued that at the end of the day, the question remains does one needs that high level of mathematics to understand the sorting algorithm? He answered no, not really, as long a student knows the pros and cons of the algorithm when applied to things like Big Data or a small set of data.

Experience of IT experts regarding students' numerical abilities

One IT domain expert said "I was once called into a tutorial laboratory where a couple of third year IT diploma students could not compute percentage increases and p6

Overall mathematical capabilities of 3rd and fourth years IT students at the UoT

An IT domain expert stated that some students spend the first term trying to get out of IT programming and when they finally get to like the course it is usually too late to catch up. One IT domain expert said that at the beginning of the second semester, he expects that IT students should have acquired the strict discipline of studying at a university. However, this has not been the case as he has noticed that on many occasions IT students in his class expect him to do the practical work while the students sit and watch.

5.6 PHASE 3

5.6.1 Mixed methods

A tentative answer to each sub-question is presented and thereafter linked to the literature reviewed that was detailed in Chapter 3. The findings of all the sub-questions are amalgamated in this section in order to draw conclusions from the findings.

Tentative answer: main research question

The main research question inquired: What is the effect of the MCI over the IT students' mathematical knowledge on entry? The tentative answer is that the effect of the MCI depends on the student's level of mathematical knowledge upon which to scaffold quantitative skills. Moreover, the effort that each student made in enhancing their newly acquired skills through practice and engagement with the quantitative technique content in the HCINCT programme determined whether or not the MCI had a positive effect on the student.

Connection to literature: main research question

Literature reviewed showed that early development of mental arithmetic skills reduces the anxiety to learn mathematics and helps students to develop the mathematical capability needed for scaffolding in later years (Ramirez *et al.*, 2016).

Tentative answer: sub-question 1

Sub-question 1 inquired: Are the post-test scores of all groups statistically different? The tentative answer to this sub-question is that there is a statistically significant difference between at least one experimental group and one control group.

Connection to literature: sub-question 1

Students' learning gains are different. The difference in a cohort's performances could be due to a new curriculum that was reformed both in content and in pedagogy (Clark, Kjeldsen, Schorcht, Tzanakis and Wang., 2016).

Tentative answer: sub-question 2

This research question inquired: What evidence do we have to suggest that the sample came from a population such that the mean score was 50? The tentative answer is that the students' pre-test scores demonstrated that most of the students' mean scores upon entry were lower than the population's mean score of 50.

Connection to literature: sub-question 2

Earlier in this chapter, the objectives of the HCINCT programme were explained according to Alexander (2013): (a) to augment the mathematical capabilities of first-year IT students; (b) to increase the throughput rates of the three-year National Diploma in IT; and (c) to equip course participants with IT skills that enable students who wish to seek employment opportunities in the IT fraternity upon course completion.

Tentative answer: sub-question 3

A successful mathematics intervention is the result of many attributes such as happy students, structured courses within the intervention and collaboration among course administrators and all stakeholders involved in the mathematics intervention. Elements of the mathematics intervention should be adjusted so that students feel peaks and troughs in a non-provocative way. The focus is on balancing the course with a sense of difficulty but also achievability.

Connection to literature: sub-question 3

Mathematics epistemology is transmitted, transferred and transformed into useful skills upon which students and their lecturers alike can scaffold new mathematical skills (Vygotsky, 1978: Anghileri, 2006; Brower *et al*., 2017). Students' positive beliefs regarding the ability to have their mathematical skills enhanced contributes to students' self-development and acquisition of the required mathematical knowledge (Sheahan, While and Bloomfield, 2015; Atmatzidou and Demetriadis, 2015; Wang, Guo and Jou, 2015). The literature reviewed suggested that operational mathematical skills helps in scaffolding the mathematical skills needed for learning advanced algorithms and advanced abstract mathematical concepts (Reiser, 2004; Anghileri, 2006; Ellis, Levy and Lauderdale, 2008; Ting, 2015).

Students must experience and see real examples of how they can use their mathematics education to gain economic, financial and social benefits for themselves, their families and their communities. The students' abilities to increase their mathematical skills in a mathematics intervention reduce their anxiety about learning quantitative and/or numerically inclined subjects (Ashcraft and Krause, 2007; Rohlwink, 2015; Demirel, Derman and Karagerick, 2015; Ramirez *et al.*, 2016;

Savelsbergh *et al*., 2016). The results supports the literature that suggest that the provision of poor mathematics education for primary school teachers results in the transfer of poor mathematical skills to primary school learners in South Africa (Clements, Sarama and Germeroth, 2016; Takane, Tshekane and Askew, 2017; Graven and Coles, 2017).

Moreover, socio-economic factors such as lack of finance, lack of resources in poor schools and uneducated parents may have affected the learners' acquisition of the mathematical knowledge needed for further studies (Gustafsson, 2005; Makgato, 2007; Bozalek, Garraway and McKenna, 2011; Gustafsson, Nilsen and Hansen, 2015). To overcome the scourge of the inadequate mathematical capability of first-year university students, the students themselves must adopt self-belief and a positive outlook towards acquiring mathematical capability (Bandura, 2006; Sangcap, 2010; Sheahan, While and Bloomfield, 2015; Bonne and Johnston, 2016). The mixed methods tools that were used were able to gain answers to the research questions and thus fulfilled the objectives of the research questions.

Tentative answer: sub-question 4

This research question inquired: Under which circumstances did the students' results improve? The mathematics results of students who had self-belief and a positive attitude towards their ability to acquire mathematics epistemology improved. In addition, students who entered the UoT with some foundational arithmetic background, even if the background were questionable, were able to acquire mathematical capability to scaffold their IT programming skills. The objective for asking this research question was to establish a criterion for successfully addressing the students' mathematics results.

Connection to literature: sub-question 4

The interview responses gained from the IT students support the literature that states there must be an aura of interest in the students to want to learn mathematics (Kwan and Wong, 2015). Before constructive learning can take place, there must be a belief system ingrained in the students regarding their learning achievements (Canfield, Ghafoor and Abdulrahman, 2012; Bonne and Johnston, 2016). Thus, achievements in mathematics are based on a student's self-belief and the cognitive strategies that the students implement to achieve their academic goals. Perceived self-efficacy and personal goals enhance motivation and performance attainment (Bandura, 2006; Applewhite, 2015). On the contrary, Reddy *et al*. (2012) argue that the acquisition of mathematical knowledge has many facets and acquiring mathematical knowledge requires collective collaboration from all stakeholders involved in the development of the student's mathematical capability.

Comments

Students consider mathematics a hindrance that has no relevance to their studies because the role of mathematics in real life is not discussed or relayed clearly to the students. Professionals such as biologists, medical technologists, neurologists and engineers who use mathematics to solve real problems are usually situated far from the students. Students need to know that mathematics and mathematicians use numeracy skills to convert huge data into useful information. The Knut and Alice Wallenberg Foundation Video 4.1 clip showcases the role of mathematics in everyday lives https://www.youtube.com/watch?v=ciddKOcUZss

Professor Manjul Bhargava suggests that mathematics is a creative subject. Therefore, one should use poetry, art, card games and magic games to teach students to learn how to come up with their way of solving mathematics problems. Professor Bhargava states the quality of teaching mathematics is the one that shows students how one comes up with mathematics theorems by following steps that are correctly logical.

Students should be encouraged to different ways of coming up with an answer. He adds that Fibonacci numbers were used in ancient India to create the musical rhymes. He argues that in school students are taught one way to come up with a mathematics answer and yet there are many ways to come with a right mathematics answer. According to Bhargava mathematics students should not be taught to memorise mathematics concepts. Instead, mathematics students should be taught how to apply mathematics concepts.

In video 4.2 https://www.youtube.com/watch?v=2MCK3eVwTw4 Professor Bhargava discusses to a group of first year University students in India that one has to find different ways of finding mathematics answers by trying different ways of solving a particular problem. Students that take time to figure out themselves how certain mathematics principle is applied in a mathematical problem solving are the ones that learn mathematics best.

Professor Bhargava's method of teaching mathematics theorems to students using art demonstrates a link between his teaching method and the one that is expressed through video 4.1 whereby mathematics should be taught such that students comprehend the use and relevance of mathematics to real life needs. Based on the information presented in Video 4.1, gaining a good grasp of basic foundation arithmetic skills is pivotal in obtaining mathematical capabilities to scaffold IT programming skills. However, the students must understand why they are learning mathematics and where and how their mathematical skills can be used beneficially.

6 CHAPTER 6: DISCUSSION, CONTRIBUTION OF THE STUDY, CONCLUSIONS AND RECOMMENDATIONS

Mathematicians do not study objects, but relations between objects. Thus, they are free to replace some objects by others so long as the relations remain unchanged. Content to them is irrelevant: they are interested in form only.

6.1 INTRODUCTION

This investigation examined the efficacy of the enhancement of the mathematical capability of first-year IT students at a UoT. The research participants must have passed either Mathematics or Mathematics Literacy at high school level to be admitted into the Higher Certificate in Communication and Technology (HCINCT) programme in 2015 (Alexander, 2013). However, the mathematics performance of many first-year IT students enrolled in the Higher Certificate in Communication and Technology (HCINCT) programme is lower than the level of Mathematics taught to 11- to 12-year-old learners in Grade 6 at primary schools in South Africa.

Eleven IT domain experts attested that there has been a progressive deterioration in the mathematical capability of IT diploma students entering university studies. The experts stated that a lack of mathematical skills among university students regardless of whether the student is a new entrant in the HCINCT programme or a third-year student enrolled in the Bachelor of Technology (IT) degree (BTech). The mathematical skills brought by IT students in transit from high school to university were inadequate to equip the students for IT studies. The problem is a global problem (Brandell, Hemmi and Thunberg, 2008). Chapter 6 affords a synopsis of the investigation and offers a review of the findings.

The chapter discusses lessons learnt from the study and their implications in practice and ends with recommendations for future studies. The embedded mixed methods approach described in Chapter 3 was used to collect data. One main research question and five sub-questions drove this study. The mathematical capabilities of the IT students were unknown at the beginning of the MCI programme. Therefore, a pre-test set at the South African Grade 6 mathematical level was administered to the students that volunteered to have the pre-test administered to them. The purpose of the intervention was to augment the participants' mathematical skills so that they had good foundational arithmetic skills upon which their IT programming skills could be scaffolded. Two categories, namely cognitive and scaffolding, that emerged from the two literature reviews were used to as guidelines to construct the qualitative research questions.

6.2 CHAPTER SUMMARIES

Chapter 1 outlined the foundation of the enhancement of the MCI programme with the 2015 students. Historical data from extended curricula and foundation programmes in related quantitative education genres were examined to gauge the landscape of the research problem. Data attesting to the lack of mathematical knowledge in students entering their first-year university studies and thus being mathematically underprepared to pursue studies that require foundational arithmetic were retrieved from two documents compiled by a consortium of academics (Higher Education Learning and Teaching Association of Southern Africa, 2009; Bozalek, Garraway and McKenna, 2011).

Chapter 2 detailed a context of the study, providing its background. Chapter 3 entailed searching for literature to establish on-going academic, general business and governmental debates on the requirements regarding the mathematical skills of first-year university students. The investigation had three focal points, namely scouting the internal UoT's arena for conducted mathematical interventions, checking the status quo within the South African context and broadening the investigation to probe the international arena for existing interventions.

Two literature reviews were conducted and presented as Chapter 3. The first literature review was used to navigate the landscape in the area of interest in order to learn from documented successful interventions. Once this process was completed, the second literature review took place. This review was conducted to determine if there were any consistencies or discrepancies between the responses that were obtained from the research participants during the one-on-one semi-structured interviews in the current study and the responses indicated in previous studies (Creswell, 2014). In total, eight constructs emerged from the literature reviews: (1) poor performance; (2) mathematics capability; (3) mathematics ability; (4) knowledge acquisition; (5) mathematics anxiety; (6) alignment; (7) mathematics self-efficacy; and (8) attitude (Siyepu, 2011; Siyepu, 2015). Research questions were compiled using these constructs. These research questions were posed to 11 purposefully selected students from the 2015 HCINCT programme. During the one-on-one interview two follow up questions were asked to interviewees that had interview responses that required more clarification and explanation.

Chapter 4 presented the methodology that was used as an engine to drive and to implement the objectives of the investigation successfully. The study used a mixed method approach for data collection, data analysis, data interpretation and data presentation to maximise the positive attributes of both the quantitative and the qualitative methods (Creswell, 1998; Sandelowski, 2000; Leech and Onwuegbuzie, 2009). The researcher adopted an anti-positivist paradigm to explore alternatives in the subjective world in order to understand the students' opinions about their mathematical skills (Burrell and Morgan, 1979; Stokes, 1997; Cloete, 2006; Cronje, 2013). This was in conjunction with a functionalist positivist paradigm to drive the study. The researcher was interested in developing solutions objectively by suggesting improvement through the tightening up on rules.

According to Sahlberg, (2006) and Calitz, (2010) regulations promote social change in ICT education, economic development and the education provided by Mathematics teachers. The conceptual framework for the investigation, the Iterative ADDIE (Van den Akker *et al.*, 2013), was used to map out the processes that measured the mathematical attributes that were required to augment the students' mathematical competencies. Kolbs, (2015)'s Experiential Learning Theory was used to administer the enhancement of MCI to the students' assessment scores retrieved from the pre- and post-test and their end-of-year QT scores.

Chapter 5 presented the findings of the investigation. An analysis of the students' assessment scores enabled identification of the existing gaps in the students' mathematical capabilities upon entry into university. Pre-test and post-test assessments scores answered the main research question that aimed to establish the efficacy of the enhancement of the MCI module with regard to the IT students' mathematical knowledge. The student responses gained from the one-on-one interviews that were conducted by the researcher were used to check conformity or non-conformity to the results that were obtained from the pre-test and post-test final-year assessment scores. The final chapter, Chapter 6, discussed findings, suggested contributions made by the study and presented conclusions and recommendations.

6.3 ANSWERS TO RESEARCH QUESTIONS

In this chapter, the research questions are used as headings and the answers to each respective research question is presented under it. The guidelines represented through Figure 6.1 are used to show a structure through which the answers to the research questions are presented in this chapter. In phase 1, all the answers to the research questions are presented; phase 2 presents only the research questions through which qualitative methods instruments were used for data collections and data analysis. Finally, phase 3 presents the amalgamation of both the research questions answers that were obtained using both quantitative and qualitative methods. The tentative answers that were presented in chapter 4 are evaluated and discussed.

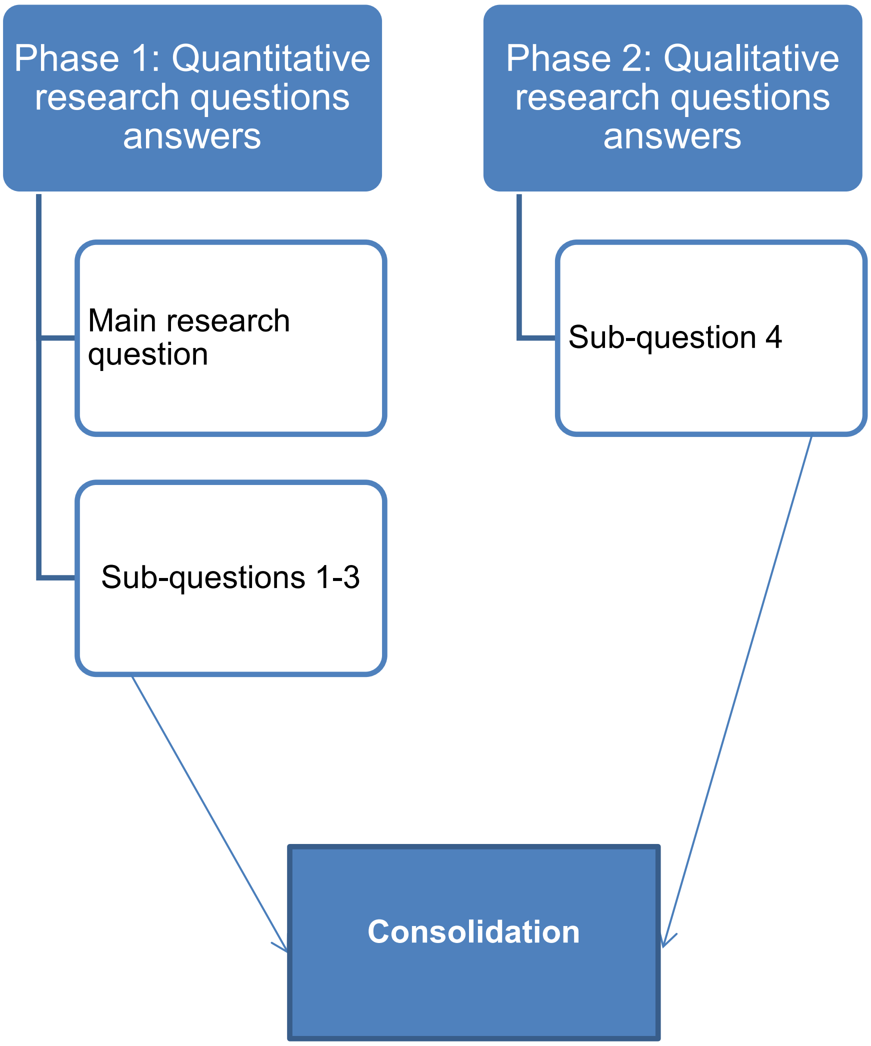


Figure 6.1: Structural design for presenting research questions answers

The structural diagram presented through Figure 6.1 was used as a guideline to present the answers to all six research questions that was in this investigation.

6.3.1 Phase 1

The structure that is used to report the answers to the research questions is depicted through Figure 6.1. All the research questions through which quantitative instruments were used to find answers to them are presented under this phase.

Main Research Question

What is the effect of the intervention programme on the mathematical knowledge of IT students upon entry into the HCINCT programme?

The answer is that the MCI had no effect on the students' mathematical knowledge upon entry into the HCINCT programme. Even though, the students' post-test scores in groups E1 and C3 increased, the descriptive statistics results suggested that there is a strong probability that the students' mathematical capabilities increased by chance.

At the conclusion of the MCI, only 36 of 147 (n = 147) students achieved the 65 aggregate score needed to be guaranteed a space in the three-year IT National diploma at the UoT where this study was conducted the following year. The majority of the students from the HCINCT 2015 programme acquired an overall mean 50 score for all 11 courses offered in the HCINCT programme. However, these students had failed two or three subjects. Hence, these failed courses had to be repeated in the following year.

Sub-question 1 Are the post-test scores of all groups statistically different?

The results of the paired t-test showed that the students' post-test mean score of 55, 31 for the experimental group E1 and the post-test mean score of 40, 45 for the control group C1 were statistically different.

Sub-question 2 What evidence do we have to suggest that the sample came from a population such that the mean score was of 50?

The students' pre-test scores were from a population other than the UoT student population of the 2015 study. This discovery affirms the fact that the HCINCT students were an autonomous group of students. Due to the fact that their matriculation mean scores upon entry were below the mean score required for admittance to any course offered by the IT Department, they were admitted into the HCINCT programme.

Sub-question 3 Is there a statistically significant difference between the HCINCT 2016 mean score and the HCINCT 2015 mean score on exit?

There is no significant difference between the HCINCT 2016 mean score and the HCINCT 2015 mean score on exit. Some IT students seemed to have increased their mathematical capabilities regardless of the group to which they belonged. A small group of students from both groups seemed to have gained no mathematics knowledge from the HCINCT programme.

6.3.2 Phase 2

Sub-question 4 under which circumstances did the students results improve?

The answer is that the students' results improved when the students assumed responsibility for acquiring mathematics knowledge themselves. The teacher's pedagogy allowed the IT students in the MCI to evaluate and criticize the quantitative techniques class tutorials content. Feedback gained from IT domain experts one-on-one interview responses was used to gain information upon which Quantitative Techniques extra class tutorials were created. IT students were allowed to evaluate their problem solving solutions.

Amalgamation of mixed methods research questions answers

In Chapter 3, the researcher speculated that the answers to the research question could assist in either filling a gap in knowledge or solving a real problem. Figure 6.2 is an illustration of the research process through which researcher embarked upon in search for answers to the research questions and solutions to the research problem.

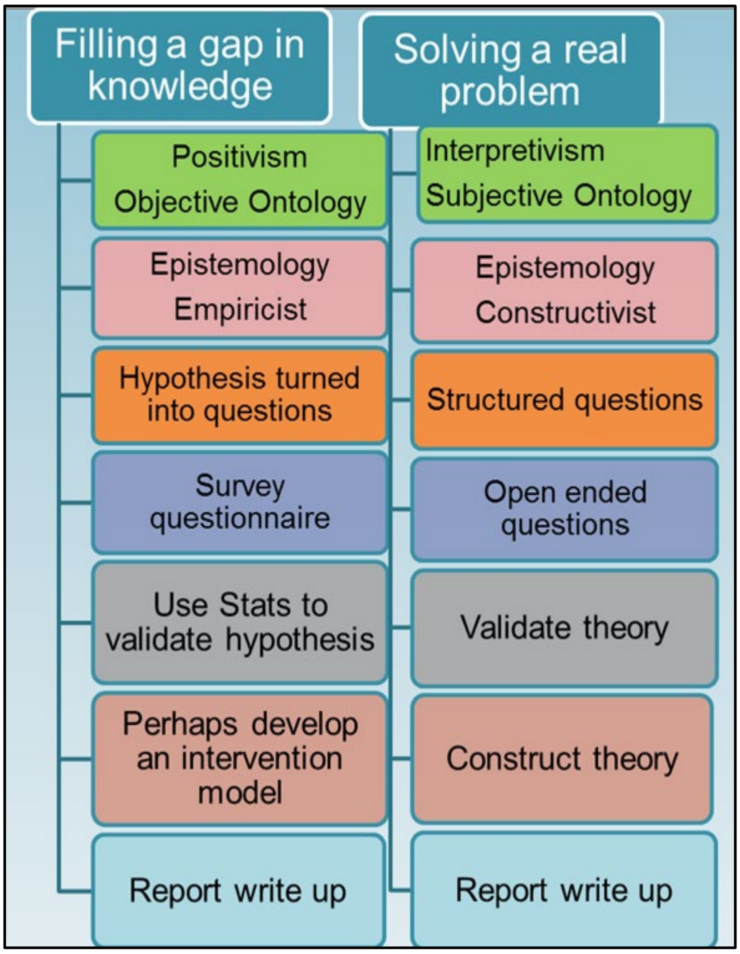


Figure 6.2: The research process

In Figure 6.2 the researcher sort to fill a gap in knowledge using quantitative methods instruments for data analysis. On one hand, hypotheses were turned into research questions. Cronbach alpha obtained from testing the constructs through which survey questionnaire questions were constructed was low. Therefore, the researcher omitted the survey questionnaire and all the IT students' survey questionnaire responses were discarded. Statistics were used to validate hypotheses and answers to the research questions were found. An intervention model was not built.

However, guidelines for implementing a successful MCI are suggested through the answers to the research questions. On the other hand, the research problem is regarding throughput rates in IT programming courses that rest in the mathematical skills of first-year IT students upon entry (Alexander, 2013). Eight constructs that emerged from the two literature reviewing processes were used as guidelines to create qualitative interview questions. These interview questions were asked to 11 purposefully selected from the 2015 HCINCT programme. The questions were open ended (see appendix I). Theory gained from different authors that were for and those authors that were against MCI programmes to students at various education genres other than mathematics were evaluated.

6.4 SUMMARY OF THE RESULTS

6.4.1 Methodological reflection

Using mixed methods for the investigation concurrently allowed for triangulation of the multiple data sources and provided answers to the research questions. Triangulation was used to check the consistency of the findings of the mixed method results (Denzin, 1970; Tashakkori and Teddlie, 2003). The mixed methods approach was conducted not because one method was perceived as weaker than the other but because the quantitative and qualitative data can be mixed for the purpose of illustrating a more complete understanding of the phenomenon being studied (Denzin, 2006; Mertens and Hesse-Biber, 2012; Fielding, 2012; Patton, 2014; Denzin, 2017).

Results of the findings that were gained while using a quantitative tool for analysis were checked against results of the findings that were attained using a qualitative tool of analysis for differentiation and for synergy (Uprichard and Dawney, 2016). Even though, Uprichard and Dawney support the fact that data integration is sensible they also argue that data integration is not necessarily the optimal outcome of mixed methods research. Engaging mixed methods in this investigation was educational and it allowed the researcher to investigate data diffractions and used data integration to counteract the effects of data triangulation that might otherwise result in data diffractions. Nine months were spent analysing and interpreting the data that had been collected through the students' assessment scores in the HCINCT programme of 2015.

When analysing the data attained through the one-on-one interviews, a similar pattern emerged for the two methods. The gaps found in the students' assessment scores were addressed by the responses of the students in the interviews. This proved the strength of using the mixed methods approach. The diffractions that emerged from both data supported the findings. Constructs that emerged from the reviewed literature with the data obtained from using the mixed methods tools were evaluated. The constructs that emerged two literature reviews were consistent, with a few additions to the constructs. The multi-faceted research approach allowed for answers to the research questions and a solution to the research problem to be found, this was regardless of whether data integration showed negative or positive enhancement in the IT students mathematics knowledge on exit.

6.4.2 Substantive reflection

During the literature reviewing process, eight constructs strongly emerged. The eight constructs were used as guidelines to construct the qualitative research questions. However, the data interpretation stage presented new constructs such as inhibition, cognitive, self-belief and edutainment. The outcomes of this research confirmed the literature reviewed that suggested that students anxiety to acquire mathematics knowledge contributed to the students lack of motivation to learn mathematics (Worthley, 2013; Rohlwink, 2015; Ford, 2015).

Similar results regarding mathematical enhancement interventions from theses of other doctoral students showed consistency with the outcome of this investigation. The trending theme indicates that augmentation of the mathematical capabilities of university students is a global challenge. It needs countries to be fully committed to the implementation of educational policies that invest sums of money into the development of Mathematics teachers from pre-school through to university level. Government policy support means equality and access to education for all. In addition, the UoT in which this study was conducted could form partnerships with other universities in the region and build capacity for TVET colleges to train students and send the students of superior quality to the universities once they have completed their one-year intervention course through the subject of Quantitative Techniques in the foundation programme.

6.4.3 Scientific reflection

Through the lessons learnt in this investigation, it became apparent that traditional ways of transferring mathematical capabilities to first-year university students needed to change from using textbooks only to also employing social media for epistemological transfer to students. Lecturing had to reflect the norms of today. Perhaps students could use social media such as Facebook, Twitter, WhatsApp, Viber, Google Hangouts to communicate and engage with mathematics in class, with lecturers and at home. In addition, students wanted to use edutainment to translate abstract mathematics theorems such as the theory of chance and the theory of logic to concrete mathematics that is easier to understand.

6.5 CONTRIBUTION

6.5.1 Theoretical and practical assessments

The study proposes that one should reduce the number of summative assessments and rather have one summative assessment conducted in the middle of the year, possibly in June, leaving the remainder of the year for the students to work through, for example, a four-stage project with three or four formative assessments linked to the project. However, such a project must have real results and it must include all students from HCINCT programme, first year to fourth year IT students at the UoT working hand in hand on such a project. For example, students could engage in translating abstract mathematics to concrete, real-life solutions for the markets such as using mathematical scales to measure the size and the patterns in creating a model robot that uses nodes to code information. Geometry could be employed to decide on the shape of the limbs of the robot, the head and so forth.

Finally, computer programs could be used by the students to form a concrete, real body for the robot that one could touch. The reason for including all students in the project would allow HCINCT students who might not have obtained adequate IT skills to write programs at this stage, to gain those skills from IT students (these would be IT students in their third and fourth years of their IT programming studies at the UOT where this study was conducted) that the researcher assumes would have obtained IT skills to write computer programs. Thereafter, the automated machine could be put to use so that students feel that they have given value. Information technology driven products like drones could be used between hospitals and pharmacies to order and to deliver medicines and tablets.

An automated machine could be programmed to remind old people in old age homes when to take their medication. Programmed automatic machines could be used in schools to teach children Mathematics. Some people that do not have time, or perhaps have no energy due to old age or sickness could use an automated grass cutting machine. The grass cutting machine could be programed on the duration it takes to cut the grass in that particular yard. The automatic grass cutting machine could be programmed with sensors so that it can detect the length and the width of the person's yard in which it has to cut the grass. Finally, an automated machined could be programmed with information on when to take an old person for a walk in the park and which route to take and for how long the walk should be.

6.5.2 Teaching methods

The contribution is illustrated using grocery items such as: 500g choice butter, 500g white sugar, 1kg whole wheat flower and 330 ml classic vanilla coca cola can to demonstrate measurements in context of weight and volume. This illustration was used to help the students to contextualize the connection between mathematics and our real life connections to mathematics. The current study advocates that we should take mathematics back from industry and return it to institutions of higher education by making changes such as breaking down calculus in courses that use mathematics continuously (e.g. physics) to enable students' success in the course.

Arts, poems, games and magic cards could be used to introduce different mathematical concepts that make teaching and learning mathematics enjoyable to both mathematics teachers and mathematics students. Universities should be driving the epistemological transfer of mathematical knowledge by engaging with industry, government and teachers continuously so that ideas are created that build synergy and corroboration. In turn, government could promote the teaching discipline through lucrative scholarships for matriculates' who pass with high marks.

Teacher expectations could be raised by allocating a few hours break per week in the lecturing schedules for at least one or two teachers in each course group in the lecturing schedule. For example at the UoT where this study conducts there were about 6 lectures in the HCINCT programme. The study showed that learning is a collaborative effort. Stakeholder engagement and involvement is at the pinnacle of addressing the current problem regarding mathematical capability. The students want to learn but do not know how to learn and thus, it is the job of the teacher to help the students learn by presenting options. Another possible route is that robotics could be used to stimulate the minds of students at UoT's.

6.5.3 Mathematics capabilities problem

The lack of mathematical capability in people transiting from high school to university is a world-wide problem. Most countries are searching for ways to enhance their education systems in order to gain better educational outputs in Science, Technology, Engineering and Mathematics (STEM); the problem in regard to STEM is not unique to South Africa. This investigation reveals that indeed, a gap exists in first-year students enrolled in subjects that require a good background in operational mathematics/foundational arithmetic. The current investigation located the origins of the participants' foundational arithmetic problems to be in their early developmental phases.

The literature reviewed confirmed these findings and indicated that other countries in the world encounter major challenges in their education systems, which are reflected in their student throughput rates and dropout and retention rates. This investigation demonstrated that, *inter alia*, the countries of Finland, Korea, Japan, Canada and Singapore have invested in the equity of their teachers. Lessons learnt are that good performance in a country's education systems requires a paradigm shift in education policy-making. In order for a country to arrive at a good education system, education academics must be involved in politics. Inequality should be eradicated to give early childhood education priority. In addition, gender equality should be promoted so that people who care most about children (mainly the mothers) have their voices heard through holding political positions in government that influence decision-making in parliament. Countries such as Finland have decision-makers from the Department of Education seated in higher education institutions.

The current study also asserts that all teachers responsible for transferring mathematics epistemology from primary school through to high school must have a master's degree. In Singapore and Finland, teachers spend many hours in retraining. The investigation showed that having a good education policy is about placing trust in teachers, learners and parents and allowing teachers to set their own syllabuses and entrusting them with this. This research found an inverse relationship between the improved quality of the MCI learning materials and the increased mathematics knowledge for those IT students that were actively involved in enhancing their mathematics capability through QT class tutorials in 2015.

6.6 RECOMMENDATIONS

The recommendations made involve support for students in their learning environment. The recommendations are divided into three categories, namely recommendations for further development of the enhancement of the MCI programme, recommendations for policy and practice and recommendations for further research. The recommended student support could also help to improve the offerings of the MCI at the South African UoT.

6.6.1 Recommendations for further development of the MCI

The MCI could be developed further if the UoT where this investigation was conducted consolidated the mathematics interventions of the different departments into one mathematics intervention programme that would cater for all the students who are identified to be in need of such an intervention. Future mathematics and/or IT orientated courses at the UoT could be aligned to the market and global trends in order to expose students more to global market demands. The Technical and Vocational Education and Training (TVET) QT lecturers could be sent on courses covering such interventions. The TVET lecturers could also watch videos on campus and engage with other lecturers at other colleges and/or universities to determine what is expected of college students by universities on entry. The UoT in which this investigation took place could align itself and collaborate with UoT's within the European Union to seek funds from the European Union under the IT innovation section.

Once received, these funds could be used in the single, newly formed mathematics intervention programme mentioned in the previous paragraph. The funds could also be used to procure more resources for the course participants to explore other learning avenues in which they could acquire knowledge of practical mathematical skills to create innovative products and services for the markets.

Outdated course materials could be removed from the syllabus to allow for new and contextualised learning materials. Class tutorials for QT could focus more on allowing students to use quantitative techniques to solve real-life problems. Students should be allowed to practice solving mathematics problems and come up with their own ways of solving mathematics problems. The QT class materials could incorporate tutorials that introduce partakers to aspects of artificial intelligence (and its subsets machine and deep learning), data mining and cyber security. To allow UoT graduates job opportunities in areas that are needed most at this present time.

Student exchanges between South African universities and international universities should be encouraged, thus providing students in the HCINCT programme with opportunities to visit similar intervention programmes in other countries. Students should be given difficult and meaningful tasks that challenge their thinking. Projects in companies should be solved by first-year IT students working in conjunction with senior-year IT students. The Mathematics curriculum and all course material must be interactive and use visual partial elements. Internet access should be given to all students via cheap but capable platforms such as Raspberry Pi.

The teaching profession should be structured at the same level as that of a medical doctor, lawyer, civil engineer, etc. through government incentives that attract the best matriculation students with lucrative bursaries towards teacher education. Scholarships should be arranged to encourage a superior output in teacher education. All Mathematics teachers from pre-school, to primary school to high school should have a master's degree in their respective teaching disciplines. Teachers across the board should constantly educate themselves and be rewarded with time off the classroom or a day off towards studies. There should be teacher seminars discussing and exchanging knowledge on relevant topics. Lecturers should invite high school Mathematics teachers and prospective learners to spend a day in a lecture room to incite interest and expose high school students and their teachers to the level of excellence expected from them as first-year university students.

Research questions (A and B) and research methods that could be used to collect data are proposed below.

Research question A: How do IT students acquire mathematics capability upon which IT programming skills could be scaffold?

Methods for research

A quantitative methods approach that uses a survey questionnaire as a method of data collection could suffice the needs of this research question. However, the researcher suggests a sample of at least 300 students to gain more students views.

Research question B: Under which circumstances did teaching methods improve the students' mathematics capabilities?

Methods for research

The research recommends using a qualitative method approach by conducting one-on-one teacher interviews to gain an in-depth understanding of the phenomenon under study.

6.6.2 Recommendations for policy and practice

The recommendation of this study is that the South African government should become involved in the enhancement of the mathematical capabilities of first-year university students by continually allocating adequate funds to universities that will allow mathematics intervention administrators to give generously to student societies within the university that promote student collaboration, unity and progressive learning.

The real change in the acquisition of mathematical capabilities for first-year university students in South Africa is hindered by the election of ministers of education and their supporters who have no knowledge about education. Education is the cornerstone of a nation's economic development; therefore, the real role players should rise up and take their place. The role of creating government policy on education is the responsibility of professors at universities, not parliament.

A minister of education should be a professor with excellent academic achievements who is supported by other professors in relevant disciplines. Teachers should be provided with continuous learning initiatives and be rewarded for every effort they make towards empowering themselves with additional mathematical capabilities. Also, staff and students should be given the liberty and equity to be innovative and creative in their lessons.

Research questions (C and D) and research methods that could be used to collect data are proposed below.

Research Question C: What is the role of government in the enhancement of mathematical capability in first-year university students?

Methods for research

An embedded mixed methods approach could be used to find answers to this research question. A combination of quantitative and qualitative methods could connect the findings. This could be advantageous. Through the use of multiple tools of analysis, the researcher is able to compare the results from the different methods and gain a more in-depth knowledge of the aspects under investigation.

Research Question D: How can government assist the UoT to establish successful a mathematics intervention programme that will equip its participants with the mathematical capabilities needed for any mathematics-related university course?

Methods for research

A mixed methods approach would be able to generate enough data for this type of investigation. One could interview 5 to 20 experts from the three universities under study in order to source information from which a research problem could be built. A survey questionnaire administered to students from the three universities could be sent to at least 300 students so that enough data could be generated.

6.6.3 Recommendations for further research

The results of the current study demonstrated a gap in the research participants' mathematical capabilities and indicated the Mathematics level of the students to be equivalent to the Grade 6 Mathematics level of the intermediary phase of the South African education system. The difficulties and challenges that were encountered during the administration of the foundation programme through class tutorials revealed that the research problem resulted from a poorly constructed primary to high school education system that was built without proper research being conducted before its implementation (Chisholm, 2005).

The recommendation made by this study is that a longitudinal investigation with dedicated Mathematics teachers at foundation phases should be conducted. The second phase of the research would be to engage primary school teachers and high school teachers in the same study so that they also contribute to the investigation. Another study could be undertaken involving high school Mathematics teachers and IT domain experts at the UoT where the current study was conducted to expose linkages and shortages regarding the missing mathematical skills in high school and university students.

High school Mathematics teachers and university experts who are also IT lecturers could engage in healthy debates regarding the problem and its solution. An investigation determining the transitional gap between high school Mathematics and the level of mathematics expected from first-year students by universities is a topic that needs to be investigated in future studies. Work on the transition from high school mathematics to university mathematics has been conducted in Canada, the Netherlands and Sweden, but no known literature exists from scholars in the Southern Hemisphere at the time of this investigation.

While gathering data from the research participants using one-on-one, semi-structured interviews, the students mentioned that they wanted to work with their hands so that they could sell their products to the markets. It was not clear whether the students wished to learn advanced mathematics modelling techniques to create artificial intelligence or not.

Therefore, future research on this would clarify exactly what the students wanted to do with their mathematical capabilities. Another recommendation would be to focus on a country such as Korea, China, Japan, Singapore and Finland or a country that has repeatedly had students outperforming their counterparts in the TIMSS and TALIS assessments and determine the reasons for this in order to apply the knowledge to South Africa.

Research question E: What is the nature of the gap in the students' mathematical capabilities on transit from high school to university?

Methods for research

A qualitative study could be conducted to gain an understanding from the students' perspective about what they think is the nature of the gap, if any, in their mathematical capabilities. In addition, one could conduct field studies and shadow Mathematics teachers at high school to determine how the subject is taught and how the university could adjust or discard some of the teaching methods in high school Mathematics that have proved to be useless. An example would be citing a formula and not being able to interpret the purpose of the formula. Hence, there is no knowledge on how to apply or when to apply such a formula, even if the student can cite the formula from back to front.

6.7 CONCLUSION

Four years were spent working on the investigation and the enthusiasm shown by the participants was evident. Their voices were heard during the one-on-one, semi-structured interviews and it can be concluded that the problem that the world is experiencing is not only due to government policy. Changes in the world demands regarding mathematical capability, the upswing of artificial intelligence requirements, the competition in the markets for global competitiveness and the products that are presented and come at a fast pace require fast-paced mathematics interventions.

The challenges that we experience today will increase in both size and number by tomorrow because our world is evolving fast. Mathematics can no longer be taught as it was five years ago, we need to evolve with times in mathematics education as well. Mathematics that allows students to create innovative products and services that generate market demands for them must be taught (Freitas, 2013). If children are only introduced to mathematics when they are six years old, it is too late. In countries such as Sweden, Canada and Japan, parents allow their babies to play with computer games as early as six months old, if not earlier. The majority of children in Africa, Brazil and India at six months old are treated like babies who simply sit, eat and do nothing.

The type of mathematics needed today is one that stimulates the brain through interactive engagement. After using the mixed methods approach to find answers to the six research questions that drove this study, the researcher concluded that the mathematics problem is a growing concern. Students do not understand why they need to acquire mathematical skills and they also do not understand the role of mathematics in their real lives. Mathematics teachers apply complex methods for transferring mathematic epistemology to university students, which increases students' anxiety towards acquiring mathematical knowledge.

Furthermore, the researcher realized that the mathematics teaching methods are not constructed such that the students could openly evaluate and criticize the content of their teaching materials. In addition, students do have enough time to reflect upon their problem solving skills by evaluating and criticizing them in a safe and friendly environment where the teacher supports and encourages students to learn from their mistakes. In the end, the researcher realized that the South African mathematics education at University does not encourage students to learn true trial and error. The learning culture in South Africa is that if one asks questions or fails a test then that student is perceived weak. Instead of recognizing that failing at is merely a reflection that a student did not grasp a particular concept and more training is required and that a student could re-write the test but arrangements have to be made with the teacher to find suitable time and suitable retesting materials.

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8 APPENDICES

APPENDIX A: PRE-TEST (GRADE 12) (SA)

Subject: Quantitative Techniques

Subject Code: QNT100S

Date of the test: ___________________

Total Marks: 36

Group Name: ______________________

Time Allocated: 1 hr 20mins

Special Instructions:

Write your name and surname, your student number, group name and the date of the assessment on the spaces provided at the top of your question paper.

Answer all the questions in the answer book.

Hand in the question paper and the answer book.

Do not use the internet to search for solutions.

Calculators and mobile phones are prohibited

You may ask for rough paper if you find a need to do so.

Requirements:

A question paper, an answer book and rough paper.

Question 1 (11 marks)

(a) The temperature of the water in the pool needs to be maintained at 22^0C. The temperature gauge used shows the temperature in degrees Fahrenheit (^{0}F). **(3)**

Convert (rounded off to the nearest degree) 22^0C to degrees Fahrenheit.

Use the following formula:

Temperature (in ^{0}F) = 32 + 1, 8 x (Temperature in ^{0}C)

(b) Simplify $\sqrt{\frac{625}{5}}$ – 20% x 1.514. Do not round down or up numbers **(3)**

(c) In a farm 60 lambs were born over a period of a week. The breakdown of the births was recorded as follows; on Monday three were born, Tuesday three more than Monday, Wednesday three more than Tuesday, Thursday three more than Wednesday and on Friday three more than Thursday. How many lambs were born on each day?

(5)

Question 2 (5 marks)

Lungile can consistently pack 9 450 apples in 170 minutes

Determine the time at which Lungile would finish packing the 9 450 apples if she started at 07:50 **(3)**

Calculate the average rate, rounded off to the nearest whole number, (in apples per minute) at which Lungile packed the 9 450 apples. **(2)**

Question 3 (9 marks)

(a) Simplify to its simplest form $\frac{1}{4}\text{yz} + \frac{7}{8}\text{yz} + \text{yz} + (-4\text{yz})$ **(5)**

(b) Find $(f \circ g)(x)$

$f(x) = x + 5$

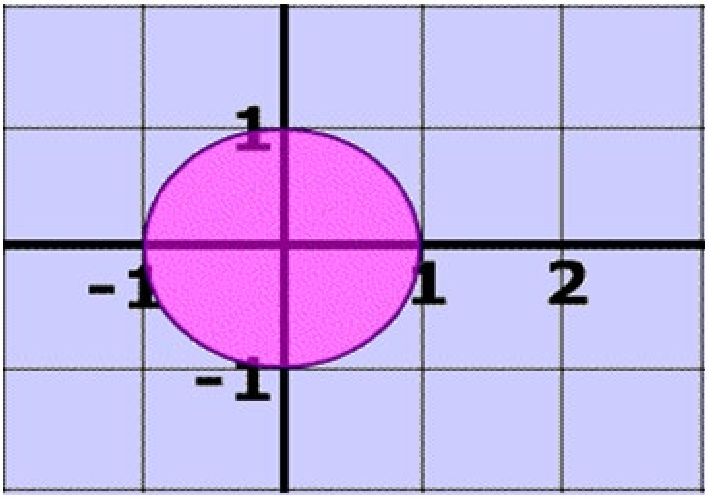
$g(x) = 3x$

Write your answer as a polynomial in simplest form $(f \circ g)(x) =$ **(4)**

Question 4 (11 marks)

(a) What is the equation of the circle pictures on the diagram below? **(3)**

•



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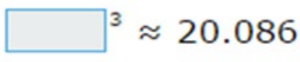
Hint! Since the radius of this circle is 1, and its centre is the origin, this picture's equation is? (b) Simplify this expression with a fraction exponent $(216)^{2/4}$ **(3)**

(c) Express $\frac{(6+1)-5(-14)}{-7}$ **(3)**

(d) Write the logarithmic equation in exponential form In 20.086≈3 

(2)

The End

APPENDIX B: PRE-TEST (GRADE 10) (SA)

Subject: Quantitative Techniques **Subject Code**: QNT100S

Date of the test: ___________________ Total Marks: 29

Group Name: ______________________ Time Allocated: 1hr

Special Instructions:

Write your name and surname, your student number, group name and the date of the assessment on the spaces provided at the top of your question paper.

Answer all the questions in the answer book.

Hand in the question paper and the answer book.

Do not use the internet to search for solutions.

No calculators allowed

Mobile phones not allowed.

You may ask for rough paper if you find a need to do so.

Requirements:

A question paper, an answer book and rough paper.

Question 1 (9 marks)

(a) $\frac{(8^2)^4}{2^5}$ (2)

(b) Express 12 °C in °F = $\frac{9}{5}$ (°C) + 32 **(2)**

(c) Simplify 6 x 4^2 **(2)**

(d) Express the mixed fraction number indicated in $5\frac{1}{4} = \frac{?}{12}$ as an improper fraction **(3)**

Question 2 (7 marks)

Express the following as algebraic expressions:

(a) Subtract d from 7 **(1)**

(b) Add 3 to a **(1)**

(c) One-half x minus four times y **(2)**

(d) Simplify as much as possible $\frac{\sqrt[4]{2x^7}}{\sqrt[8]{64x^6}}$ **(3)**

Question 3 (9 marks)

Evaluate the following:

(a) $(8 + 6^2) \div (2^3 - 4)$ **(3)**

(b) (6 + 1) ◦ (5-(-14) ÷ -7 **(3)**

(c) {3 ◦ [10 ÷ (6-4)]} + 2 **(3)**

Question 4 (4 marks)

Lulu works an ordinary 8-hour shift per day in a week for five days Monday to Friday. However, from time to time her employer calls her for overtime work. If she works on a Saturday, she has to be paid time and a half and if she works on a Sunday, she has to be paid double time. Lulu's hourly pay rate is R8.00 per hour.

This week from Monday to Friday Lulu worked for 8hrs each day.

On Saturday, she worked for 4.5hrs and on Sunday, she worked for 3 hours. How much will Lulu earn for this week (Monday to Sunday)? Show all your calculations.

(4)

The End

APPENDIX C: PRE-TEST (GRADE 6) (SA)

Subject: Quantitative Techniques **Subject Code:** QNT100S

Date of the test: ___________________ Total Marks: 29

Group Name: ______________________ Time Allocated: 1hr

Special Instructions:

- Write your name and surname, your student number, group name and the date of the assessment on the spaces provided at the top of your question paper.
- Answer all the questions in the answer book.
- Hand in the question paper and the answer book.
- Do not use the internet to search for solutions.
- No calculators are allowed
- Mobile phones not allowed.
- You may ask for rough paper if you find a need to do so.

Requirements:

A question paper, an answer book and rough paper.

Question 1 (14 marks)

(1.1) Express 75 ^{0} F in ^{0} C degrees using the formula ^{o} C = $\frac{5(°\text{F}-32)}{9}$ **(4)**

(1.2) Evaluate $\frac{(8+6^2)}{(2^3-4)}$ **(3)**

(1.3) Find the missing denominator for the numerator 12 in this problem $5\frac{1}{4} = \frac{?}{12}$

(4)

(1.4) $\frac{(6+1)\,(5-(-14))}{-7}$ **(3)**

Question 2 (11 marks)

(2.1) Simplify $\frac{(8^2)^4}{2}$ **(3)**

(2.2) Solve such that you have two proper fractions left $1\frac{1}{3}$ **:** 2 **(2)**

(2.3) $\frac{120-25\,(3)}{12+24\div 8}$ + 10 **(3)**

(2.4) $\frac{3(2pa^2+4a^5\,p^2)}{3p}$ **(3)**

Question 3 (4 marks)

(3.1) Factorize 2^4 and show how you got to the final answer **(2)**

(3.2) Solve 6 * 4^2 (indicate how you got to your final answer) **(2)**

The End

APPENDIX D: POST-TEST (SA)

Subject: Quantitative Techniques **Subject Code:** QNT100S

Date of the test: ___________________ Total Marks: 30

Group Name: ______________________ Time Allocated: 1hr

Special Instructions:

- Write your name and surname, your student number, group name and the date of the assessment on the spaces provided at the top of your question paper.
- Answer all the questions in the answer book.
- Hand in the question paper and the answer book.
- Do not use the internet to search for solutions.
- No calculators are allowed
- Mobile phones are not allowed.
- You may ask for rough paper if you find a need to do so.

Requirements:

A question paper, an answer book and rough paper.

Question 1 (14 marks)

(1.1) Express 75 ^{0} F in ^{0} C degrees using the formula ^{o} C = $\frac{5(°\text{F}-32)}{9}$ **(4)**

(1.2) Evaluate $\frac{(8+6^2)}{(2^3-4)}$ **(3)**

(1.3) Find the missing denominator for the numerator 12 in this problem $5\frac{1}{4} = \frac{?}{12}$

(4)

(1.4) $\frac{(6+1)\,(5-(-14)\,)}{-7}$ **(3)**

Question 2 (11 marks)

(2.1) Simplify $\frac{(8^2)^4}{2}$ **(3)**

(2.2) Solve such that you have two proper fractions left $1\frac{1}{3}$: 2 **(2)**

(2.3) $\frac{120-25\ (3)}{12+24\ \div 8}$ + 10 **(3)**

(2.4) $\frac{3(2pa^2 + 4a^5\ p^2\ )}{3p}$ **(3)**

Question 3 (4 marks)

(3.1) Simplify 2^4 and show how you got to the final answer **(2)**

(3.2) Simplify 6 x 4^2 (indicate how you got to your final answer) **(2)**

The End

APPENDIX E: REQUESTING STUDENT PARTICIPATION

Dear Student

I am conducting research towards a doctoral degree in the field of information and technology (IT). I would like to gain your consent towards participating in one- on-one interviews towards my doctoral studies. Participating in the study is on a voluntary basis and your interview responses will be anonymous.

Should you wish to withdraw from participating in the research, you may do so at any time during the duration of the research; then your interview responses will be withdrawn from the research and your information will not be used for the study.

There is no remuneration for partaking in the study. However, should you wish to participate in the research, your name and your identity will not be revealed and it will not be known by the researcher either.

The research is not for gain for the researcher. Its purpose is only for academic studies by the Universities in order to help to improve the throughput rates of future IT students in the Higher Certificate in ICT (HINCT). All data gathered will be stored and archived in a safe and locked environment at the University of Technology.

Yours Sincerely

Jane Nelisa Freitas

Lecturer IT, FID

Student Consent: Sign_________________________Date:____________________

APPENDIX F: ETHICS CLEARANCE (SA)

Office of the Research Ethics Committee	Faculty of Informatics and Design

At a meeting of the Faculty Research Ethics Committee, ethics approval was granted to MS JANE NELISA FREITAS student number 215299515 for research activities related to the DTech: Information Technology degree at the Faculty of Informatics and Design, Cape Peninsula University of Technology.

Title of dissertation/thesis:	An intervention to enhance the Mathematics capability of first year Information Technology students at a university of technology

Comments

Research activities are restricted to those detailed in the research proposal. **Ethics approval is granted on condition that a consent letter from CPUT Management is submitted to the Faculty Research Ethics Committee, allowing the candidate to collect data at CPUT.**

Signed: Faculty Research Ethics Committee	27/7/2016 Date

APPENDIX G: QUALITATIVE INTERVIEW QUESTIONS

1. How has the MCI prepared you for the IT programming courses in the HCINCT programme?

2. What was the effect of the QT class tutorials on your mathematical skills?

3. How were your experiences with the MCI?

4. What comprises good mathematical capabilities for you?

5. Under which circumstances did your mathematical capabilities improve?

6. How were your numerical skills developed during your primary school education?

7. How has your high school mathematics education contributed to your mathematical skills?

8. To what degree did your attitude towards acquiring mathematical knowledge help you?

9. How has high school mathematics education prepared you for your first year university studies?

Follow up question:

If the MCI was so easy, why is it that you were one of the 95% of students who failed a third pre-test set at the level of South African Grade 6 content?

APPENDIX H: IT DOMAIN EXPERTS INTERVIEW QUESTIONS

The interview protocol associated with data collection from IT Domain Experts comprised the following six open-ended questions:

1. How are the mathematics capabilities of first year IT students on entry at the UoT?
2. What do you think is needed to enhance the students' mathematics capabilities?
3. Which numerical skills do you think the students lack on entry into the UoT to study IT programming studies?
4. In your view do the students need numerical capabilities to study IT programming studies at the UoT where this study conducts?
5. Could you comment on your experiences with IT students' numerical abilities during their IT programming studies?
6. How have you experienced the overall mathematical capabilities of 3rd year and fourth years IT students at the UoT?

Jane Nelisa Freitas: Doctor of Technology: Informatics Candidate 2015 to 2019. **Lecturer:** Quantitative Techniques, Accountingand Finance, Cape Peninsula University of Technolology, January 2015 to July 2017 nelisa.j.freitas@gmail.com

Student Supervision

From September 2017 to October 2018 I supervised 3 master of business administration (MBA) students from the University of the Witwatersrand (WITS). All three students graduated in 2018. From 2015 to 2016 I supervised two Bachelor of Technology students from Cape Peninsula University of Technology (CPUT) both students graduated in 2016.

Academic papers

“ An intervention to enhance the mathematics capability of first-year information technology students at a University of Technology: quantitative methods”.

This paper was re-submitted to the African Journal Research in Mathematics, Science and Technology Education on the 10th of July 2019. This was after the researcher had addressed the journal editors comments and suggestions. The due date for re-submitting the paper was given by the journal editor.

“ Determining students mathematics gaps on transit from high school to first year University studies. The Nordic Studies in Mathematics Education (NOMAD) journal editor made suggestions and recommendatons to the researcher on this paper and asked the researcher to re-submit the paper (work in progress).

“Evaluating the effect of the mathematics intervention administered to first year information Technology students”. Paper submitted to the International Journal of Research in Undergraduate Mathematics Education (work in progress).

Other academic engagements

I presented a paper at the International Conference in Business, Science and Management Conference, Vrije Universtity, Amsterdam, Netherlands, 12 July to 14 July

2019. SAARMSTE 2018 conference papers reviewer. PhD guest at Chalmers University of Technology, Department of Mathematics, statistical Matheamtics and Applied Statistics, from January 2017 to June 2017.

Book chapters

Co-authored a Quantitative Techniques book that was piloted by 4 TVET Colleges in the Western Cape, South Africa from January 2016 to December 2017. Professor Bennett Alexander was the project sponsor.