INVESTIGATING THE PROBLEM-SOLVING PROFICIENCY OF SECOND-YEAR QUANTITATIVE TECHNIQUES STUDENTS: THE CASE OF WALTER SISULU UNIVERSITY

by

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Declaration

I hereby declare that **Investigating the problem-solving proficiency of second-year Quantitative Techniques students at Walter Sisulu University** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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Signature Date

(Ms L Bester)

Abstract

Investigating the problem-solving proficiency of second-year Quantitative Techniques students at Walter Sisulu University.

Quantitative Techniques is traditionally a subject with a poor pass rate at Walter Sisulu University. In search of a turnaround strategy, the purpose of this study was to determine the level of problem-solving proficiency of Quantitative Techniques students, which is suspected to influence achievement in this subject. A descriptive survey design was used in this research. Second-year ND (Marketing) students (128) took part in the study. A questionnaire and a written test were used to collect data. A profile of participants' problem-solving was determined. Their weaknesses and strengths in problem-solving were investigated. The problem-solving proficiency of participants with regards to the biographical variables of Gender, Age, Mathematics background and whether they took Data Handling training at school or not were explored.

A model, based on Polya's four stages of problem-solving, was used to measure the students' level of problem-solving proficiency, which was 59,16%. Findings suggest that the students achieved highest in understanding a problem (72,29%) and making a plan to solve the problem (73,77%). They are weakest at interpreting their results (29,38%). MANOVA results showed no statistical significance for the biographical variables. The univariate results suggest that age, Data Handling training at school and Gender could affect problem-solving proficiency. Since the findings of this study indicate a strong relationship between participants' problem-solving proficiency and their actual achievement, some intervention is recommended. An intervention could be in the form of a section on problem-solving in the course, supplemental instruction or an introductory course. Course and curriculum content should be revised to address students' proficiency in problem-solving.

Key terms: Problem-solving, problem-solving proficiency, Quantitative Techniques, problem-solving models, Mathematics, Age, Data Handling, Gender.

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I would like to acknowledge the second-year Quantitative Techniques students who took part in this research. Thank you to Mr D Venter who assisted me in analysing the empirical data, Dr A Weimann for editing my work and Mrs L Wood for correcting the language.

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List of Abbreviations

DOE……...Department of Education

FET………Further Education and Training

PCL………Participant Confidence Level

PSP……….Problem-Solving Proficiency

WSU……...Walter Sisulu University

CHAPTER 1

INTRODUCTION

1.1 Background

The Walter Sisulu University (WSU) in the Eastern Cape, South Africa is guided by the Mission Statement of the Department of Education (DOE) which emphasises the goal of preparing students for the economic and social needs they will be confronted with as adults: '... creating a vibrant further education and training system to equip youth and adults to meet the social and economic needs of the 21st century.' (Department of Education, 2013). 'Increasingly, society demands that its workers are able to solve real world problems' (Hock, 2008, p. 1). This view agrees with Yunus, Tarmizi, Abu, Nor, Ismail, Ali, Bakar and Hamzah (2006, p. 86) who asserted that 'The demands of a changing workplace and a complex global society have raised expectations regarding thinking and problem-solving among students.' Students should, therefore, be equipped with higher-order thinking skills required for problem-solving to mould citizens to handle the challenges of the new knowledge era (Hock, 2008).

Quantitative Techniques is a sub-section of Statistics, which is a branch of Mathematics that deals with the collection, organisation, analysis, and interpretation of numerical data. Statistics, determined for a sample (a subset of a population), is especially useful in drawing general conclusions about the characteristics of the population under study. Statistics is therefore, a tool used to solve real world problems.

Generally, between 120 and 200 students register for Quantitative Techniques at WSU annually. Quantitative Techniques is a compulsory second-year subject for the National Diploma in Marketing at this institution (See also Section 1.5.5). It is offered in the second-year syllabus and is not part of any other course at this institution. Students come with varied backgrounds in Mathematics, e.g. Mathematics (Grade 12), Mathematics Literacy (Grade 12) and some without any Mathematics. Statistics, or Data Handling and Probability, as it is known at school level, is a section of the Mathematics curriculum in secondary education. The Grade 10 and Grade 11 curriculums consist of compulsory and optional assessment standards for Data Handling (Wessels, 2008). In the years before the data collection for the study took place there were no compulsory assessment standards for Grade 12 Data Handling. Grade 12 is the phase in which methods learned in the previous grades are used to investigate and solve problems, but according to Wessels (2008), in practice many teachers drop the optional Grade 12 Assessment Standards for Statistics from the curriculum.

Quantitative Techniques is traditionally a 'difficult' subject at WSU (See Section 1.4). Figure 1 gives the pass rates from 2006 to 2010. In 2010 the pass rates for the two Quantitative Techniques modules were 40% and 49% respectively. Students often have to repeat this course two or three times. The following topics are covered in the course:

Module 1:

- Visual representation of data
- Calculation of statistical measures
- Calculation of basic probabilities
- Probability distributions

Module 2:

- Sampling and sampling distributions
- Estimation
- Hypothesis testing
- Linear regression and correlation
- Index numbers
- Time series analysis and forecasting.

Students must achieve 50% or higher in the examination at the end of the module to succeed in this course. A student is allowed to write the examination if his or her semester mark, made up by marks from weekly tutorial tests and two semester tests, is 40% or higher. Figure 1 illustrates the changes in the pass rate of the two modules between 2006 and 2010.

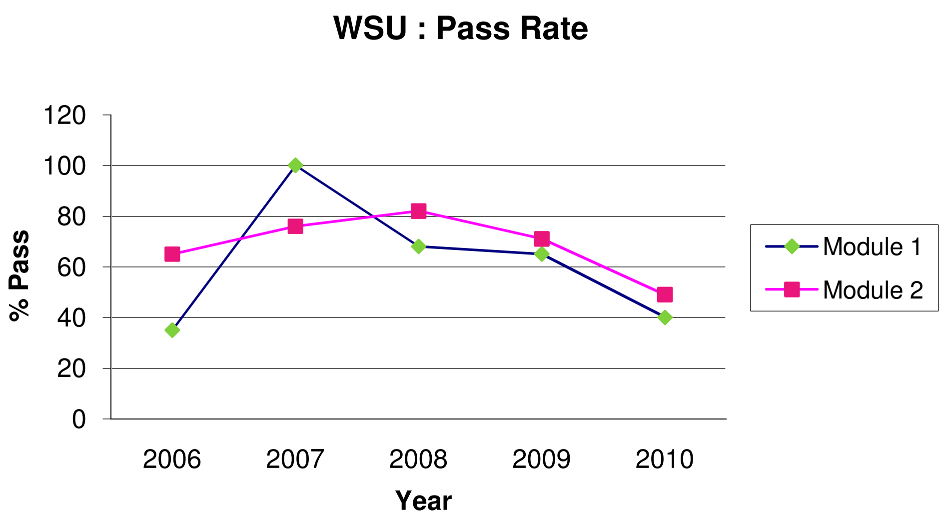


Figure 1. Quantitative Techniques Pass Rate (WSU 2011).

My view is that the students' weak, or lack of, problem-solving proficiency (PSP) is one factor that contributes to the low pass rate. A study by Johnson and Kuennen (2006) indicated 'that basic mathematical skills are an important determinant of student success in elementary statistics …' (p. 10). The authors concluded that

> 'the importance of mathematical skills may go beyond merely the ability of students "to do the math", it may also help students to analyse and reason quantitatively, and to understand and interpret statistical measures' (p. 10).

Omiwale (2011, p. 6) found that 'the better the problem-solving ability of students, the better their achievement in Physics would be.' Since Quantitative Techniques belongs to the scientific field, I suspected that students with high problem-solving ability might achieve higher than those with lower problem-solving ability and wanted to investigate the topic. Nevertheless, Wu (2004) asserted that the identification of problem-solving ability profiles would be of little use if intervention strategies cannot be identified as well. It is against this background that I considered investigating students' problem-solving proficiency in Quantitative Techniques to be of paramount importance. I felt that this research had the potential to reveal the need for intervention and identify possible intervention strategies.

Universities elsewhere in South Africa and abroad offer courses similar to Quantitative Techniques, offered at WSU. The results of this study could therefore be significant for the problem-solving proficiencies of students taking these courses, as well as courses in other sciences.

1.2 Problem of the study

This study seeks to investigate the problem-solving proficiency (PSP) of second-year Quantitative Techniques (a compulsory subject) students enrolled in the National Diploma in Marketing (ND: Marketing) at WSU. The researcher has lectured this course over a period of five years and has noticed how the pass rate has decreased every year (See Figure 1 on p. 3). This study is an effort to acquire further information on the state of PSP of Quantitative Techniques students with a view to developing relevant intervention strategies to address the decreasing trend.

1.3 Research questions

The study addresses the following questions:

1. What is the level of problem-solving proficiency (PSP) of Quantitative Techniques students at WSU?
2. What problem-solving weaknesses or strengths, with regards to problem-solving proficiency, do Quantitative Techniques students at WSU display?
3. Which students, with respect to

   3.1 Age,

   3.2 Mathematics or Mathematics Literacy background and

   3.3 Data Handling training or experience , or none,

   display better problem-solving proficiency?
4. Which Gender group tends to display a better problem-solving proficiency?

1.4 Rationale of the study

R. Buckminster Fuller (1895 - 1983), American Architect, Author, Designer, Inventor and Futurist said:

One common experience of all humanity is the challenge of problems.

One of the most important objectives of Mathematics education is to develop students' PSP, that is their critical, creative and divergent thinking skills (Fan & Zhu, 2000; Kandemir & Gϋr, 2009). More specifically, some researchers assert that algebraic reasoning helps students to develop mathematical problem-solving skills that generalise within mathematics and across disciplines (Vergnaud, 1983; Milgram, 2005; Vogel, 2008; Ketterlin-Geller & Chard, 2011). Quantitative Techniques as a component of Mathematics entails problem-solving. Students of Quantitative Techniques need to display higher order thinking skills involved in the solving of problems. Wu (2004, p. 3) asserted that 'as many higher order thinking skills are involved in problem-solving tasks, well-developed problem-solving instruction can promote students' cognitive and metacognitive processes to develop higher order thinking and prepare them to take on the challenges of the workplace demands in the future.' My study is in addition a means to measure the students' readiness to function optimally at a cognitively high level.

Zakaria and Yusoff (2009, p. 233) noted Schoenfeld's (1985) assertion that students 'are not actually weak in solving problems, but lack the skill to marshal strategies that help to solve particular problems'. They (Zakaria & Yusoff, 2009) also noted that students' failure to solve problems begins during the reading of the question. Students with good reading skills tend to understand the words, sentences, concepts and questions better and also knew how to plan and implement strategies to solve problems. Research also shows that students can produce the correct 'solution' for a problem without understanding the solution or the underlying problem (Jolliffe, 1990). Quantitative Techniques students have to deal with problems stated verbally. This study will provide information on the students' proficiency to solve these kinds of problems, since they would be required to solve such problems in their work places. There is, therefore, a need for an uncomplicated instrument to assess, and point out weaknesses and strengths, of the various aspects of problem-solving proficiency in the classroom, rather than a complex analysis which could be time consuming and intricate. An investigation into the PSP of students can, as a result, lead to the adoption of measures to improve students' PSP, which may spill over into other subjects and also improve their overall performance. Improved PSP will be an investment in their future professions.

A shortage in literature on PSP and Age indicates a need to investigate the PSP of different age groups. Some studies targeted specific age groups (e.g. Lindberg, Hyde, Peterson, & Linn, 2010; Lamson & Rogers, 2008) and assessed their Mathematics performance, but do not compare PSP of different age groups. Many studies (e.g. Latterell, 2003; Wu & Adams, 2006; Benson, 2007; Voskoglou, 2008; Pimta, Tayruakham, & Nuangchalerm, 2009; Taplin, 2009; Zakaria & Yusoff, 2009; Sangcap, 2010; Che, Wiegert, & Threlkeld, 2012) document the strong association between Mathematics and problem-solving, but research evidence by Garfield & Ben-Zvi (2007) does not agree that a student will succeed in Statistics if they are good at Mathematics. No study was found which investigated the association between PSP and Mathematics background, i.e. whether a student took Mathematics, Mathematics Literacy or neither at school. From literature it is not clear what association between Data Handling training and Mathematics at school exists and how it influences PSP. Research seems also inconclusive with reference to Gender difference in problem-solving skills. I believe that these gaps can be addressed in my study.

The study will also help point out the weaknesses in the school syllabus or methods of teaching at schools that may hinder the development of appropriate problem-solving skills. There is evidence that teachers tend to focus more on the mastery of procedures rather than on concepts and how concepts interrelate (Loucks-Horsely, Stiles, Mundry, Love, & Hewson, 2010). If students can be equipped with improved PSP, their performance could improve and they could leave WSU with an improved level of cognitive reasoning.

Results of the study could indicate a need for remediation, e.g. revising relevant Grade 12 Mathematics at the beginning of the course. It will also be helpful to the University, particularly to lay down course pre-requisites, modify course content and curriculum development. The results may also be useful to other instructors who teach courses which involve problem-solving at WSU and other universities. Awareness of the possible PSP profile of prospective students could lead to the adoption of measures to improve these students' PSP.

1.5 Definition of terms

The interpretation of terms such as 'problem', 'problem-solving' etc. is different for different people. The following discussion attempts to define the meaning of the key terms used in this research.

1.5.1 Problem.

The Oxford Advanced Learner's Dictionary (2012, p. 70) defines a problem as ‘a thing that is difficult to deal with or to understand’ or ‘a question that can be answered by using logical thought or Mathematics’. Schoenfeld (1985, p. 74) agrees with this definition when he defines a problem as: ‘A doubtful or difficult question, matter of enquiry, discussion or thought; a question that exercises the mind’.

From a cognitive psychologists’ point of view: ‘Any definition of a *problem* should consist of the three ideas that (1) the problem is presently in some state, but (2) it is desired that it be in another state and (3) there is no direct, obvious way to accomplish the change.’ (Mayer, 1992, p. 5). This definition of a problem is supported by Krulik and Rudnick (1989) and Zakaria and Yusoff (2009, p. 232) who asserted that ‘A problem is a situation in which an individual must find solutions that are not immediately obvious’.

In this study I shall adopt Schoenfeld’s definition of a problem as a situation that needs a solution that is not immediately obvious and that exercises the mind.

1.5.2 Problem-solving.

Krulik and Rudnick (1989, p. 5) define problem-solving as ‘the means by which an individual uses previously acquired knowledge, skills and understanding to satisfy the demands of an unfamiliar situation. The student must synthesise what he or she has learned and apply it to a new and different situation’.

Mayer and Wittrock (2006, p. 287) assert that problem-solving is 'cognitive processing directed at transforming a given situation into a goal situation when no obvious method of solution is available'.

Of problem-solving or procedures for getting solutions (heuristics), in his book of 1945 George Polya states: 'The aim of heuristic is to study the methods and rules of discovery and invention' (p. 112).

The Gestalt psychologist Duncker wrote in 1945 that:

> a problem arises when a living creature has a goal but does not know how this goal is to be reached. Whenever one cannot go from a given situation to the desired situation simply by action, then there has to be recourse of thinking. Such thinking has the task of devising some action, which may mediate between the existing and desired situations (p. 2).

In this study problem-solving will be regarded as the engagement of knowledge, abilities, understanding and mental processes required to resolve a situation with no obvious solution method to the problem solver.

1.5.3 Problem-solving proficiency (PSP).

In this study problem solving proficiency (PSP) will refer to the ownership of the set of stage specific skills necessary to carry out the four stages of Polya's problem-solving model. This definition of problem-solving proficiency includes anything that impacts the problem-solving process, i.e. knowledge and cognitive skills required to solve a problem. This means that a student is a proficient problem solver if he or she can solve a problem by carrying out the four stages of Polya's problem-solving model successfully.

1.5.4 Level of problem-solving proficiency.

George Polya (1945) summarised the stages of problem-solving in a four step model as follows:

1. Understanding the problem
2. Devising a plan
3. Carrying out the plan
4. Looking back.

Polya's model will be used in this study as instrument to determine the students' PSP. It will measure how well students perform in each stage of Polya's model, i.e. they *master* a stage when the answer is one hundred percent correct, *master* a stage *partially* when the answer for the specific stage is only partially correct, *do not master* a stage when the answer for the particular stage is completely wrong or they have made *no attempt* to solve the problem. 'How well' students do in each stage of solving the problem is defined as the *level of the PSP* in this study.

1.5.5 Quantitative Techniques.

Quantitative Techniques is a compulsory module in the second-year of the National Diploma in Marketing course at WSU. It consists of the collective package of mathematical and statistical skills and techniques applied to analyse quantitative (numerical) data which can be applied to solve business-related problems, i.e. finding information in quantitative data. The objective of the course is to make students aware of the systematic approach in the subject and to build this concept into further managerial decision-making tasks. It also serves as a basis for the more specialised fields of study.

1.6 Organisation of dissertation

This dissertation consists of six chapters.

Chapter One provides an introductory orientation to this study. The background for the study is given. The research questions through which the problem of the study will be addressed are presented. The rationale of the study is discussed and some key terms are defined.

Chapter Two is a literature review where possible models of problem-solving are discussed. The conceptual framework for this study is also presented in Chapter two. The conceptual framework for this case study is an information processing approach. Polya's problem-solving model was selected to obtain an overview of students' PSP.

Chapter Three discusses the research methodology, design, population, instruments, data collection, data analysis techniques and ethical issues.

Chapter Four is a report of the data analysis. The scoring of the test scripts is described. Data Analyses employed to the four research questions are described and the results summarised.

The results of the data analysis are discussed in Chapter Five. Findings are an attempt to answer the four research questions.

Chapter Six gives an overview of the study. Conclusions are reported. Limitations of the study are pointed out. Recommendations and suggestions for further research are made.

CHAPTER 2

LITERATURE REVIEW

2.1 The concepts of attribute, skill, ability, competency and proficiency

In my literature study I came across various terms, e.g. attribute, skill, ability, competence and proficiency, which were used in studies of problem-solving. The concepts of attribute, skill, ability, competence and proficiency do not have unique definitions among researchers. Below is a discussion of examples from literature which illustrates this statement.

As a point of departure I found the following meanings for the terms attribute, ability, skill, competent and proficient (South African Student's Dictionary, 1996):

> attribute: qualities, properties, characteristics or features of something
>
> ability: state of being able to do something
>
> skill: cleverness or expertness at doing something that comes from a lot of practice or from natural ability
>
> competent: something that is of satisfactory or acceptable standard
>
> proficient: do something well or with skill.

The term *attributes* was used by Woods, Hrymak, Marshall, Wood, Crowe and Hoffman (1997). They asserted that students who are problem-solvers exhibit the following attributes:

1. Are aware of the processes used.
2. Use pattern matching to quickly decide whether a situation is a problem or an exercise.
3. Apply a variety of tactics and heuristics.
4. Emphasise accuracy rather than speed.
5. Write down ideas and create charts/figures, while solving a problem.
6. Monitor or reflect on the processes used.
7. Are organised and systematic.
8. Are flexible (keep options open, can view a situation from different perspectives/points of view).
9. Draw on the pertinent subject knowledge and objectively and critically assess the quality, accuracy, and pertinence of that knowledge/data.
10. Are willing to risk and cope with ambiguity, welcoming change and managing distress.
11. Are willing to spend time reading, gathering information and defining the problem.
12. Use an overall approach that emphasises fundamentals rather than trying to combine various memorised sample solutions.

The mentioned attributes come from both domains in Bloom's taxonomy: cognitive domain (2, 3, 5, 8, 10) and the affective domain (1, 4, 6, 7, 9) (Mourtos, Okamoto, & Rhee, 2004). This observation suggests that before students acquire the skills necessary to tackle open-ended problems, they need to have, or develop, certain attitudes. The first four attributes listed by Woods et al. is the minimum level of competence required in both the affective and the cognitive domain to perform as an expert problem-solver (Mourtos, Okamoto, & Rhee, 2004). From this, it would seem to me that what Woods et al. regard as attributes of problem solvers, Bloom views as skills.

Some researchers do not always distinguish between ability and skill. Adams (2007, p. 13) considers 'anything that impacts the problem-solving process', which includes knowledge and cognitive processing, a problem-solving skill or problem-solving ability. Carroll (1996) defined an ability, or skill, as the capability to perform some defined task or solve a problem. Krutetskii (1976) formulated a structure for mathematical ability, which could be developed by students (Kang, 2012). Then again, Wu (2004) asserts that ability is usually a latent attribute for a person. According to Wu and Adams (2006) a problem-solving skill involves linking the demands of a problem-solving task to the cognitive processes. Problem-solving skills are also identified by Mayer and Wittrock (2006) as knowledge and cognitive procedures. In my view Clement and Konold (1989) supported this notion when they organised problem-solving skills as *stage-specific* skills, i.e.

i. Comprehending and representing
ii. Planning, assembling and implementing a solution
iii. Verifying the solution.

This corresponds roughly with the model for problem-solving developed by Polya (1957).

Zakaria & Yusoff (2009) measured Algebraic problem-solving skills as: problem translation, problem integration, solution planning and monitoring and solution execution. To me these skills are rather problem-solving proficiencies.

After Polya, Schoenfeld (2007) concluded that proficient problem-solving includes knowledge, strategies, metacognition and beliefs and dispositions. During my search for literature I could not find studies about problem-solving proficiency of Quantitative Techniques (or Statistics) students, but I found a study about the statistical competence level of secondary school pupils (Vega, Cardonoso, & Azcarate, 2010). In this study various skills were measured to determine problem-solving competence levels. Were these not perhaps proficiency levels? Long, Dunne and Craig (2010) studied proficiency in Mathematics by identifying levels of competence, which in my view confuses the matters of competency and proficiency. It is clear that there is no agreement on the definition of all these terms, i.e. attribute, ability, skill, competence and proficiency. My opinion is that proficiency is on a higher level than competency and I, therefore, will use the term proficiency in my study.

2.2 Models for problem-solving

There seems to be a dearth of literature on problem-solving proficiency and Quantitative Techniques. Given how problem-solving proficiency (PSP) and Quantitative Techniques has been defined in Section 1.5, literature related to the two aspects will be drawn from their respective derivatives. That is, PSP, as an apparent composite of problem-solving skills and problem-solving ability, has its literature largely drawn from these aspects. Quantitative Techniques as a derivative of Statistics has its literature taken largely from studies on Statistics and in some instances from Mathematics, given that in a way Quantitative Techniques is also a derivative of Mathematics. Nevertheless, the discussion on literature pertaining to my research problem attempts to develop a justification for my study.

After numerous studies over years some aspects of problem-solving still do not seem to be understood. Voskoglou (2008, p. 26) asserts:

> while the literature supports that control and metacognition are important for problem-solving success, more information is needed to understand how these behaviours are manifested during problem-solving and how they interact with other problem-solving attributes reported to influence the problem-solving process.

Early research to describe problem-solving focused on the process involved in solving a problem. Carson (2007) regards the knowledge base and the transfer of the knowledge, not the content-free heuristic, as the most essential elements of problem-solving. Recently the focus has moved to the characteristics of the problem-solver that contributes to the success of solving a problem (Schoenfeld, 1987; Mayer & Hegarty, 1996; Stillman & Galbraith, 1998; Steffanutt & Albert, 2003; Wu, 2004; Carlson & Bloom, 2005; Yimer & Ellerton, 2006; Adams, 2007; Marriott, Davies, & Gibson, 2009; Kang, 2012). In the field of teachng and learning, research to identify cognitive skills involved in problem-solving is basically divided into two approaches, a factor-analytic approach and an information processing approach (Wu, 2004).

Hill (1997) points out that factor-analytic theorists such as Carroll (1993) and Halfin (1973) are concerned with the identification of the distinct abilities as required in a problem-solving task, e.g. the ability to observe, analyse, visualise, communicate, interpret, test, design, manage, etc.. An example of research to identify problem-solving skills, through a factor-analytical approach, is a study by Steffanutti and Albert (2003), in which they designed a model or set-theoretical formal framework for skills assessment of an individual in a simulated environment. According to them a model, which they call a ‘problem space’, is constructed for a learning environment. A skill and a knowledge space are then drawn from this model and thus can be used for assessment and training. The learning environment for the use of this model needs to be specified in a highly structured way, therefore, it is suited only for some fields of study.

Another example of a factor-analytical approach is the content-free problem-solving evaluation tool developed by Wendy Adams (2007). Forty-four distinct skills essential to solving problems can be identified with the instrument developed by Adams (2007). These skills were classified as knowledge skills, cognitive process skills and beliefs. It is my view that these three aspects are essential in successful problem-solving in Quantitative Techniques.

The factor-analytical approach has been criticised by some researchers since the interpretation of some factors can be difficult and open to debate (Wu, 2004). Wu (2004) asserted that it is very difficult to make sense of the factors involved in problem-solving through factor analysis, since the cognitive processes underlying problem-solving are very complex and intertwined. Some researchers, for example Nandakumar (1994), indicated that exploratory factor analysis may identify factors that are irrelevant to cognitive processes. According to Wu (2004) and Adams (2007), confirmatory factor analysis is for that reason preferred by researchers such as Jöreskog and Sörbom (2006), to test a hypothesis about factors associated with cognitive processes. It is clear that a factor-analytical approach can be a very long and vague process.

Carson (2007) pointed out that information processing theorists, for instance Dewey, Polya, Krulik and Rudnick, are more concerned with the identification of the stages of problem-solving, rather than the separate skills involved in the problem-solving process. The information processing approach identifies the cognitive processes needed in sequential steps in problem-solving. These processes can be used as triggers for students to improve their problem-solving procedures (Wu, 2004). Wu and Adams (2006) assert that 'problem-solving strategies indentified using the information processing approach, are more likely to be of practical use in the classroom' (p. 96).

Since the cognitive factors that play a role in problem-solving proficiency (PSP) cannot easily be addressed directly in a classroom, I decided on an information-processing approach for this study. It is for this reason that I decided to study existing models of scientific problem-solving with an information processing approach as they will help in understanding the problem-solving proficiency of Quantitative Techniques students. I, therefore, focused only on related research with similar procedures. Research on problem-solving models with a factor-analytical design is, therefore, beyond the scope of this study.

Literature on problem-solving proficiency and Quantitative Techniques is limited. I could not find a study on problem-solving in Quantitative Techniques. My search for related studies was extended to problem-solving in Statistics. I found a study by Marriott et al. (2009) who, in a project to teach, learn and assess statistical problem-solving, produced an instrument to assess students' abilities to solve statistical problems. According to Marriott, Davies and Gibson (2009), Anderson and Kratwohl (2001) revised Bloom's taxonomy of educational objectives as remembering, understanding, applying, analyzing, evaluating and creating. Based on the work of Anderson and Kratwohl (2001), Marriott et al. (2009) came up with a four stage Data Handling Cycle that is also linked to Anderson's revised Bloom's taxonomy and referred to it as a problem-solving approach (PSA) for statistical problems. The four stage Data Handling Cycle which is referred to as PSA is as follows:

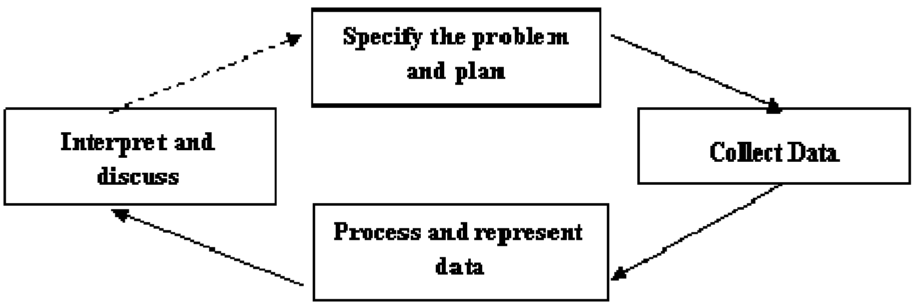


Figure 2. The PSA approach (Marriott, Davies, & Gibson, 2009, p. 2)

In my view remembering, understanding, applying, analyzing, evaluating and creating, i.e. Anderson's revised taxonomy, are underlying cognitive processes of the four PSA stages (Figure 2). Marriott et al. (2009) found that the participants in their study (year 8 and year 9 pupils) had a poor performance in the process and interpret stages of problem-solving. I strongly believe that PSA can also be useful when teaching students how to solve problems in Quantitative Techniques.

I have extended the search for related studies to the field of Mathematics in general. Such studies would be helpful since the focus of my study is problem-solving proficiency in what may be perceived as a mathematically orientated area of study. Mathematics instruction is largely drill-and-practice in many South African schools. According to the Gestaltists such instruction minimises mathematical thinking (Schoenfeld, 1987a). It should be noted that drill-and-practice enables students to master procedures for solving problems and as such meanings of, and links amongst, concepts cannot be figured out. It is these meanings and links between concepts that enable generalisations to be made of what is known and thus facilitate conceptual understanding (Loucks-Horsely et al., 2010). Learning with conceptual understanding enables remembering and reformulating what is known and applying what is known to generate new knowledge as well as solving problems, particularly the non-routine problems (Schoenfeld, 1985). These are the sort of problems that students of Quantitative Techniques also have to solve or deal with. The current study is, therefore, also a way to determine the extent to which the Quantitative Techniques students learn with understanding.

The oldest and probably most important model that warrants mention is Polya's model for solving mathematical problems, which he developed in 1945. Polya's (1957) work presents two themes on the nature of mathematical thinking, which are order and discovery (Schoenfeld, 1987a). With *order* and *discovery* Polya referred to the systematic discovery of the structures of specific mathematical areas through solving systematically arranged problems, as well as the systematic exposition of a 'procedure' for discovery and invention. He, therefore, studied patterns of productive thinking that lead to successful mathematical problem-solving and proposed a problem-solving heuristic to solve problems of any kind.

> [First,] we have to see clearly what is required. Second, we have to see how the various items are connected, how the unknown is linked to the data, in

> order to obtain the idea of the solution, to make a plan. Third, we carry out our plan. Fourth, we look back at the completed solution, we review it and discuss it (1957, p. 5).

As already indicated in Section 1.5.4 Polya also came up with a problem-solving model with four stages. The four stages are as follows:

1. Understand the problem
2. Devise a plan
3. Carry out the plan
4. Look back and check.

In the mid-to-late 1970s researchers in artificial intelligence and mathematics education cast doubt about the solidity of the heuristical foundations established by Polya, but in the late 1980's Schoenfeld (1987a, p. 290) asserted that 'empirical evidence gained in the past decade indicates that Polya's intuitions may have been right'.

My view is that each stage in the PSA cycle of Marriott et al. for solving statistical problems, referred to before, generally corresponds with Polya's stages of problem-solving (Table 1). If a student is able to complete the four stages of Polya's procedure, the student should then be able to deal with the four-stage PSA cycle of Marriott et al. for solving statistical problems. Therefore, I believe that Polya's model and the PSA cycle are analogous.

Table 1. *Comparing the PSA with Polya's problem-solving model*

PSA	**Polya's stages**
Remember/Understand : *Plan*	Understand the problem
Analyse : *Collect*	Devise a plan
Apply : *Process*	Carry out the plan
Evaluate and Create : *Interpret*	Look back

In my literature study I also found many mathematical problem-solving studies which used models that are similar to Polya's model, e.g. models developed by Krutetskii (1976), Schoenfeld (1987), Mayer and Hegarty (1996), Stillman and Galbraith (1998), Carlson and Bloom (2005), Wu and Adams (2006), Yimer and Ellerton (2006), Zakaria and Yusoff (2009) and Weber and Carlson (2010). These models were used successfully in studies of problem solving.

Krutetskii (1976) studied the mathematical abilities of school children. This served as motivation for Kang (2012) to develop ways of enhancing students' mathematical capabilities. Krutetskii summarized the mathematical abilities he indentified in the following three stages:

1. Obtaining mathematical information:
   - The ability for formalised perception of mathematical material, for grasping the formal structures of a problem.

2. Processing mathematical information:

    - The ability for logical thought in the sphere of quantitative and spatial relationships, number and letter symbols; the ability to think in mathematical symbols.
    - The ability for rapid and broad generalisation of mathematical objects, relations, and operations. (Generalization)
    - The ability to curtail the process of mathematical reasoning and the system of corresponding operations; the ability to think in curtailed structures. (Condensation)
    - Flexibility of mental processes in mathematical activity. (Flexibility)
    - Striving for clarity, simplicity, economy, and rationality of solutions. (Being economical)
    - The ability for rapid and free reconstruction of the direction of a mental process, switching from a direct to a reverse train of thought (reversibility of the mental process in mathematical reasoning). (Reversibility)

3. Retaining mathematical information:

    - Mathematical memory (generalized memory for mathematical relationships, type characteristics, schemes of arguments and proofs, methods of problem-solving, and principles of approach). (Structural memory) (Krutetskii in Kang, 2012, p. 10).

‘These components are closely interrelated, influencing one another and forming in their aggregate a single integral system, a distinctive syndrome of mathematical giftedness, the mathematical cast of mind’ (Krutetskii in Kang, 2012, p. 8). I believe that Krutetskii’s three stages of obtaining, processing and retaining mathematical information is an information processing approach.

Schoenfeld (1985) then presented a theoretical framework characterising stages of competency in problem-solving areas which is based on Polya’s structure. Schoenfeld is well known for his work on metacognition. His model, therefore, combines Polya’s stages with information processing theories and places more emphases on the importance of metacognition. The stages of this framework for the analysis of mathematical behaviour are:

i. Resources
ii. Heuristics
iii. Control and belief systems (Schoenfeld, 1985).

According to Biryukov (2004) Schoenfeld later modified his model to include,

i. Resources/knowledge base
ii. Heuristics/analysis/problem-solving strategies
iii. Exploration/monitoring and control (metacognition)
iv. Planning/implementation
v. Verification/interpretation

Several studies in mathematics problem-solving point to the role of metacognition in the problem-solving process (Gomez-Chacon, 2000; Foong, 2002; Teong, 2003; Biryukov, 2004). Özsoy and Ataman (2009) asserted that 'instruction of metacognitive strategy has a distinctive impact on increasing the problem solving achievement levels of students' (p. 79). In a way my study will also assess students' metacognitive processes in a course they take as part of their studies, since metacognitive processes give attention to students' abilities to monitor and control their own cognitive processes used during problem-solving (Artz & Armour-Thomas, 1992).

Mayer and Hegarty (1996) studied mathematical problem-solving in terms of four components: translating, integrating, planning and executing. I consider these four components vital for dealing with the type of problems students have to solve in Quantitative Techniques. In this subject students get tasks in the form of a word problem which must be solved. They have to translate the verbal information into numbers and symbols, formulate a plan to solve the problem, execute the plan and also report their findings in verbal form.

Stillman and Galbraith (1998) followed an information processing approach to study the cognitive and metacognitive aspects of problem-solving of females in a senior secondary Mathematics course. The four component areas of information-based activity which they selected for attention were: information gathering, information representation, search and information processing and information validation. These components are similar to the four stages of Polya's problem-solving model, i.e. information gathering ↔ understand a problem, information representation ↔ make a plan, search and information processing ↔ execute the plan and information validation ↔ look back and check.

Carlson and Bloom (2005) developed a problem-solving taxonomy for the domains (levels) of intellectual behaviour that are important in learning. The domains (levels) of this classification are:

i. Resources (understanding, knowledge, procedures)
ii. Control (plan, monitor, make decisions, conscious metacognitive acts, etc.)
iii. Methods (general strategies, computations, accessing resources, etc.)
iv. Heuristics (work backwards, observe symmetries, substitute numbers, alter given problem, subdivide problem)
v. Affects (attitudes, beliefs, emotions, ethics)

Arguably Carlson and Bloom's problem-solving taxonomy somehow resembles Schoenfeld's model. None the less, Weber and Carlson (2010) felt that Polya and Schoenfeld only focused on what students are *doing* when they solve problems and did not attend to the mental processes employed when they are solving problem. They studied ways of thinking that lead students to demonstrate specific problem-solving strategies. My study also investigates this issue with respect to Polya's problem solving model. Weber and Carlson's research was based on Carlson and Bloom's taxonomy and Polya and Schoenfeld's structures to identify students' behaviour during problem-solving. Their conclusion was that orientation is a key phase when solving mathematical problems. Problem orientation attends to students' thinking in problem-solving, involving making sense of, planning and constructing possible techniques of solution (Weber & Carlson, 2010).

Wu and Adams (2006) developed a model for problem-solving based on the needs to link the demands of problem-solving to the cognitive processes. They identified important skills for solving mathematical problems as well as specific weaknesses students have in solving problems. They developed a problem-solving model that was based on the needs to link the demands of problem-solving to the cognitive processes. Wu and Adams' model has four dimensions as follows:

i. Reading/extracting all information from the question
ii. Real-life and common sense approach to solving problems
iii. Mathematics concepts, mathematisation and reasoning
iv. Standard computational skills and carefulness in carrying out computations

With this model Wu and Adams demonstrated a method to unravel the complex cognitive processes situated in a task which can provide a problem-solving proficiency (PSP) profile of students. This framework does not make provision for the assessment of reflection or the interpretation of the results that the student may find.

Though many studies on problem-solving reported in literature suggest structures to identify and classify metacognitive strategies, Yimer and Ellerton (2006) felt that they fell short of providing a research base for assisting students to develop the ability to monitor and regulate their own problem-solving activities. Yimer and Ellerton studied aspects of mathematical problem-solving of preservice teachers and proposed a five-phase model as follows: engagement (understand the problem, i.e. Polya's stage 1), transformation-formulation (make a plan, i.e. Polya's stage 2), implementation (execute the plan, i.e. Polya's stage 3), evaluation and internalization (look back and check, i.e. Polya's stage 4). According to Yimer and Ellerton their model is different from others because reflection is part of each phase as well as the entire model. They consider internalisation as a separate phase.

Zakaria and Yusoff (2009) developed a model to study problem-solving skills in Algebra, which was based on Mayer's (1992) model. Zakaria and Yusoff's model consists of problem translation and integration (understand the problem, i.e. Polya's stage 1), solution planning (make a plan, i.e. Polya's stage 2) and monitoring and solution execution (execute the plan, i.e. Polya's stage 3). It is my view that the lack of a stage for interpretation of the results in this model is a shortcoming.

I also looked at studies on problem-solving in the other sciences. When studying the problem-solving strategies of Biochemistry students at the University of New Mexico, Anderson, Mitchell and Osgood (2007) developed an on-line method, Problem Based Learning (PBL), to assess students' proficiency of problem-solving in their large-enrolment classes. It is a tracking method to monitor student use of problem-solving strategies to provide targeted help to groups and individual students in the PBL case discussions. To assess students' problem-solving performance, their discussions were tracked, analysed and graded according to the following domains:

Is the student:

i. Generating reasonable hypotheses?
ii. Proposing an appropriate investigative strategy?
iii. Correctly analysing supplied data?
iv. Integrating conclusions from the data?
v. Reflecting on their own conclusions?

The problem-solving domains of their model correspond with the stages of Polya's model, i.e. understand the problem ↔ generate hypotheses, make a plan ↔ proposing an investigative strategy, execute the plan ↔ analyse and look back and check ↔ integrate and reflect. With this tool it was possible to provide targeted help to groups and individual students and measure improvements in students' problem-solving strategies. Problem areas of Biochemistry students were identified after the evaluation of their problem-solving skills and then necessary interventions were designed to better the problem areas. The same evaluation tool can be also used to reassess the students' problem-solving skills after an intervention to establish whether there was an improvement. I, therefore, contend that this tool has the potential to measure the PSP of Quantitative Techniques students to identify problem areas that may require some intervention and to reassess the students' PSP after intervention.

Litzinger, Van Meter, Firetto, Passmore, Masters, Turns, Gray, Costanzo and Zappe (2010) developed an Integrated Problem-solving (IPS) model to assess the problem-solving skills of students of Statics. When the IPS model is compared with Polya's stages of problem-solving, it is clear that all the components of the IPS model are contained in Polya's model: recognition (understand the problem and make a plan, i.e. Polya's stage 1 and 2), framing (execute the plan, i.e. Polya's stage 3) and synthesis (evaluate the solution, i.e. Polya's stage 4). Litzinger, et al. felt that the findings of their study advanced the understanding of the struggles that students have with problem-solving and also suggested a means for intervention to address these struggles. This instrument also has the potential to measure the PSP of Quantitative Techniques students.

Broadening the focus, I found the study by Yunus, Tarmizi, Abu, Nor, Ismail, Ali et al. (2006) who studied the problem-solving abilities of Malaysian university students, which was based on a model similar to Polya's model. They included students from the faculties of Engineering, Science, Computer Science, Medicine, Management and Law in their study and measured problem-solving abilities of these students according to a) problem definition and formulation, i.e. understand the problem, b) generation of alternatives, i.e. make a plan, c) decision-making, i.e. execute the plan and d) solution, implementation and verification, i.e. look back and check. One of their findings was that students lacked skills in implementing and verifying solutions. Even though my study focused on university of technology students, I argue that some parallels can be drawn between my study and that by Yunus et al. (2006) because both deal with post-matriculation students. It will, therefore, be interesting to study the PSP of a university of technology's students.

I also looked at the process of creative problem-solving. According to Shaw and Runco (1994, p. 37) 'Creativity is producing something new and different through lending what is possessed'. Alex Osborn and Sidney Parnes, who are the pioneering leaders in the field of creativity, developed a model based on creative problem-solving in the 1950s (Lloyd, 2010). The steps of the Osborn-Parnes Creative Problem-solving (CPS) model were modified by Scott and Treffinger (2008) into a three-process-stage that encompasses six explicit steps as follows:

i. Understanding the problem (identify the goal, wish, or challenge, gather data and clarify the problem)
ii. Generate ideas
iii. Planning for action (select and strengthen solutions and plan for action).

Each step in the Osborn-Parnes CPS process begins with divergent thinking, a broad search for many alternatives, which is followed by convergent thinking to narrow down the alternatives. This characteristic of divergent and convergent thinking distinguishes the Osborn-Parnes CPS process from other creative problem-solving methods. Kandemir and Gür (2009) indicated that students' mathematical problem-solving skills can be developed through CPS training.

No research on problem-solving and Quantitative Techniques in South Africa could be found. A study by Long, Dunne and Craig (2010) investigated locally the levels of competence of Grade 7 to Grade 9 Mathematics learners. They used multiplicative conceptual field (MCF) groups and a Rasch measurement model, which was another way of evaluating problem-solving proficiency, and asserted that these instruments gave clear evidence on which concepts and skills learners had mastered and those which they had not. Since I decided to follow an information processing appraoch to measure problem-solving proficiency, Long et al.'s study cannot be used for comparison in the current research,.

Dhlamini (2012) investigated the effect for implementing context-based problem solving on Mathematics learners' performance. I believe that the problem-solving skills he assessed could be organised into the four stages of Polya's problem-solving model. This study showed that the participants were weakest in verifying their solutions. To study the effect of a structured problem-solving strategy on performance in Physics in disadvantaged South African schools, Gaigher, Rogan, and Braun(2006) formulated a seven step assessment approach, which summarised successful approaches reported in literature. Again, it is my view that these seven steps can be reduced to Polya's model.

An information processing approach, which identifies the cognitive and metacognitive processes needed in problem-solving, seems to have the potential to identify problem areas and the improvement thereof when solving problems in Quantitative Techniques. I believe that a simple model, such as Polya's model, has greater potential to be implemented in a classroom to measure problem-solving proficiency than a sophisticated, complex model. It is against this backdrop that I am interested in profiling the PSP of students in Quantitative Techniques.

A summary of the problem-solving models with an information-processing approach studied during this research is given in Table 2.

It is my view that most of the models in Table 2 are minor variations of Polya's model, given that they have progressive stages of a problem-solving process. Mayer and Hegarty (1996), Wu and Adams (2006), Zakaria and Yusoff (2009), as well as the CPS process of Osborn-Parnes (Scott & Treffinger, 2008), end their problem-solving processes with the execution of a plan. These models do not include a stage for reflection. I believe that this is a shortcoming in the models that the mentioned researchers used in their studies, highlighted by the fact that researchers (Schoenfeld, 1987; Carlson & Bloom, 2005; Yimer & Ellerton, 2006; Anderson, Mitchell & Osgood 2007) have lately developed models that incorporate a stage for reflection in the problem-solving process.

Table 2. *Summary of problem-solving models*

MODEL	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Polya (1945)	**Understand**	**Devise a plan.**	**Carry out the plan.**	**Look back.**	
Osborn-Parnes (1950s)	Understand	Generate ideas	Plan action		
Krutetskii (1976)	Obtaining information	Processing information		Retaining information	
Schoenfeld (1985)	Knowledge	Analysis and Exploration	Implementation	Interpretation	
Mayer & Hegarty (1996)	Translate	Integrate and Plan	Execute		
Stillman & Galbraith (1998)	Collect information	Information representation	Processing	Validation	
Carlson & Bloom (2005)	Understand/ knowledge	Control/plan	Methods	Heuristics	Affects
Wu & Adams (2006)	Extract information	Plan	Mathematisation and Carry out the plan		
Yimer & Ellerton (2006)	Engagement	Transformation-Formulation	Implementation	Evaluation	Internalisation
Yunus et. al. (2006)	Problem definition	Generate alternative	Decision-making	Implementation and verification	
Anderson, Mitchell & Osgood (2007)	Hypothesis	Strategise	Analyse	Integrate and Reflect	
Marriott, Davies & Gibson (2009)	Specify problem and plan	Collect data.	Process and represent	Interpret and discuss	
Zakaria & Yusoff (2009)	Problem translation and Problem integration	Solution planning and monitoring	Solution execution		

Litzinger, Van Meter, Firetto, Passmore, Masters, Turns, Gray, Costanzo and Zappe (2010)	Recognition	Framing	Synthesis	

This literature review convinced me that Polya's four stage problem-solving model can be used as a way of determining the problem-solving proficiency Quantitative Techniques students, certainly also because it was used successfully in other studies in different sciences.

The importance of stage one of Polya's model, i.e. to understand the problem clearly, is underlined by the inclusion of this stage in all the models used in the studies of problem-solving mentioned before. Research by Mayer and Hegarty (1996, p. 51) emphasised that:

> The source of difficulty in mathematical problem-solving is in problem representation rather than solution execution. The source of difficulty in problem representation is in comprehending relational statements rather than assignment statements, and the source in understanding relational statements involves using a problem model strategy rather than a direct translation strategy.

The middle stages of the models summarised in Table 2 are similar to stages two and three of Polya's model, i.e. make a plan and carry it out. Stage two in the models of Krutetskii (1976) and Litzinger et al. (2010) correspond with stage two and three of Polya's model, as do stages two, three and four of models by Schoenfeld (1985), Carlson and Bloom (2005) and

Yimerton and Ellerton (2006). Models by Stillman and Galbraith (1998), Yunus et al. (2006), and Marriott, Davies and Gibson (2009) correspond stage by stage with Polya's model.
The last stage of eight of these models (Polya; Schoenfeld; Stillman& Galbraith; Carlson & Bloom; Yimer & Ellerton; Yunus et al.; Anderson, Mitchell & Osgood; Mariott, Davies & Gibson; Litzinger, et al.) carries the notion of reflection, which agrees with stage four of Polya, i.e. 'look back'.

It will, therefore, be of interest to investigate problem-solving proficiencies in Quantitative Techniques, based on Poly's problem-solving model.

2.3 Review of literature on problem-solving proficiency and Age, Mathematics background, Data Handling and Gender

Literature on problem-solving proficiency and Age, Mathematics background, Data Handling and Gender will be discussed separately in the following sub-sections.

2.3.1 Problem-solving proficiency and Age.

In literature no research on the comparison of problem-solving proficiency of groups with varied ages related to Quantitative Techniques was found. Some research points to the fact that Age could play a role in mathematical problem-solving proficiency. Lindberg, Hyde, Peterson and Linn (2010) asserted that Gender differences in Mathematics performance of primary and secondary school learners varied, along with other factors, as a function of age. Lamson and Rogers (2008) found that older adults' mathematical problem-solving patterns in strategy choice are considerably more varied than younger adults' patterns, which suggests diverse explanations for differences in memory performance. In most studies of problem-solving specific age groups are targeted, i.e. PSP of different age groups are not compared.

2.3.2 Problem-solving proficiency and Mathematics background.

The students in my class come from varied Mathematics backgrounds. In South Africa secondary school learners have the option of taking Mathematics Literacy instead of Mathematics in Grade 10 to Grade 12. Mathematics Literacy was introduced in January 2006 in Grade 10 classes as an alternative to the Mathematics program and runs across the Further Education and Training (FET) band, i.e. Grade 10 to Grade 12. The Mathematics Literacy qualification is viewed as suitable for learners who wish to continue onto courses at higher education level that do not have a significant mathematical content, or into vocational courses or employment (Venkatakrishman & Graven, 2006). Therefore, I searched for studies on problem-solving proficiency (PSP) of Mathematics students, PSP of Mathematics Literacy students and PSP of students who took neither in Grade 12.

The strong relationship between Mathematics and problem-solving has been documented widely in literature (e.g. Latterell, 2003; Wu & Adams, 2006; Benson, 2007; Voskoglou, 2008; Pimta, Tayruakham, & Nuangchalerm, 2009; Taplin, 2009; Zakaria & Yusoff, 2009; Sangcap, 2010; Che, Wiegert, & Threlkeld, 2012). The ability to solve problems, learnt through Mathematics, is also a vehicle to develop logical thinking and can provide students with mathematical knowledge and enhance transfer of these skills to unfamiliar situations

(Taplin, 2009). Carson (2007) also stressed that a knowledge base and transfer of that knowledge are the most essential elements of solving problems. Johnson and Kuennen (2006) found that Mathematics skills are important determinants of student performance in Statistics. Mathematics skills help students analyse and reason quantitatively, as well as understand and interpret statistical measures (Johnson & Kuennen, 2006). Furthermore, Mathematics, which in the years before data collection took place, included in Grade 12 in South Africa an optional module for Data Handling (Wessels, 2008), is the only subject offered at South African schools which can prepare learners for a subject such as Quantitative Techniques. On the other hand, some research evidence does not indicate that a student will succeed in Statistics if they are good at Mathematics (Garfield & Ben-Zvi, 2007). I would like to include investigation of this indication in my research.

Mathematics Literacy does not imply detailed knowledge of calculus, differential equations, topology, analysis, linear algebra, abstract algebra, and complex sophisticated mathematical formulas, but rather a broad understanding and appreciation of what Mathematics is capable of achieving (DOE, 2003; Ojose, 2011). Literature pertaining to problem-solving profociency (PSP) and Mathematics Literacy is sparse. No study regarding PSP and Mathematics Literacy could be found, neither of comparisons of PSP of Mathematics and PSP of Mathematics Literacy. To find out what role problem-solving plays in Mathematical Literacy as a school subject, I decided to look at the assessment of Mathematical Literacy in South Africa. In a review of the four-level assessment taxonomy for Mathematical Literacy prescribed by the DOE in South Africa, Venkat, Graven, Lampen and Nalube (2009) analysed the Mathematical Literacy examination papers of 2008. They concluded that problem-solving only comes into play at Level 3 of the assessment taxonomy and that a learner could obtain

60% without doing any problem solving and mathematical reasoning. I also referred to a report written by The Program for International Student Assessment (PISA), a system of international assessments that measures capabilities in Reading literacy, Mathematics Literacy and Science Literacy of 15-year-olds every three years. PISA was first implemented in 2000 and is carried out by an intergovernmental organisation of industrialised countries, the Organization for Economic Cooperation and Development (OECD). Six levels of Mathematical Literacy proficiency, and not specifically problem-solving proficiency in Mathematical Literacy, is measured in this study, which can give an indication of the participants' problem-solving proficiency in Mathematical Literacy. Unfortunately South Africa was not included in this project, but the results for 2012 showed that in Mathematical Literacy, 55% of the participants scored at level 5 or above in Shanghai, while 9% scored at level 5 or above in the U.S.A. The U.S.A. scored lower than the average performance for most OECD countries (PISA, 2012). Ojose (2011), referring to Mathematical Literacy taught at school in the U.S.A., concluded that schools in the U.S.A. failed to produce mathematically literate citizens. I suppose this could be an indication that problem-solving proficiency in Mathematics Literacy is generally low.

No literature was found with reference to the problem-solving proficiency of students who took neither Mathematics nor Mathematics Literacy in Grade 12. Similar to Ojose (2011), my view is that such students probably also use mathematical principals to solve problems without being aware of it.

2.3.3 Problem-solving proficiency and Data Handling.

There is a shortage of literature in research on PSP and Statistics, or Data Handling as it is known at school. As mentioned before, Data Handling was taught as an optional assessment module of Mathematics in Grade 12 in South African schools (Wessels, 2008) in the years before data collection took place. Johnson and Kuennen (2006) researched the basic Mathematics skills of students taking an introductory course in Economics and Business Statistics at a university. They found that, although higher Mathematics skills such as Algebra, Geometry and Trigonometry were not significant, basic Mathematics skills were an important determinant of students' success in the course. They felt that mathematical skills might help students to analyse and reason quantitatively.

After reviewing the research on teaching and learning Statistics, Garfield and Ben-Zvi (2007) asserted that a student will not necessary succeed in Statistics if they are good at Mathematics. Their view is that 'statistics education is emerging as a discipline in its own right, not an appendage to mathematics education.' (Garfield & Ben-Zvi, 2007, p. 389). They seem to see Statistics as a separate field of learning apart from Mathematics. This view is supported by Marriott, Davies and Gibson (2009) who, after studying school learners up to the age of sixteen, asserted that teaching statistical concepts and ideas are fundamental to developing learners' statistical literacy.

2.3.4 Problem-solving proficiency and Gender.

Reports on problem-solving proficiency and Gender tend to focus on primary and secondary school learners (e.g. Schoenfeld, 1987; Clement & Konold, 1989; Wu & Adams, 2006; Marriott, Davies, & Gibson, 2009; Zakaria & Yusoff, 2009; Pimta, Tayruakham, & Nuangchalerm, 2009). TIMSS (2011) reports Gender differences in Mathematics performance. It was found that fourth grade boys on average had higher achievement than girls in the reasoning domain, but eighth grade girls outperformed boys on average in both the knowing and reasoning domains. PISA (2012) reports that male-female performance differences in Mathematics Literacy are statistically significant and that on average male participants scored higher than female participants.

I could not find any research specifically on problem-solving proficiency (PSP) and Gender of university students who take Quantitative Techniques. Research with reference to Gender difference in problem-solving skills seems inconclusive. Johnson and Kuennen (2006) found that Gender was one of the important determinants of student performance in an introductory Statistics course at the University of Wisconsin. Some studies show that there is a definite difference between problem-solving proficiency of male and female students. A study of problem-solving abilities of students at a Malaysian university indicated that male students outperformed their female counterparts (Yunus, et al., 2006). Gender differences in mathematical problem-solving are also pointed out by other studies (e.g. Gallagher, DeLisi, Holst, McGillicuddy-DeLisi, Morely, & Cahalan, 2000; Sangcap, 2010; Che, Wiegert, & Threlkeld, 2012).

Several other studies point out that there was no Gender difference in Mathematics performance. Results of a study of students at a matriculation college found no significant difference in problem-solving skills in Algebra based on Gender (Zakaria & Yusoff, 2009). Two studies by Lindberg, Hyde, Peterson and Linn (2010) on primary and secondary school learners provide strong evidence of Gender similarities in Mathematics proficiency. Other studies confirm the view that there are no Gender differences in mathematical problem-solving performance (Caplan & Caplan, 2005; Adeleke, 2007; Vilenius-Tuohimaa, Aunola, & Nurmi, 2008; Samuelsson, 2010).

In his review of literature related to Gender differences in mathematical problem-solving patterns, Zhu (2007) reports that Gender differences do exist with regards to mathematical problem-solving patterns. He asserts that 'gender differences in mathematical problem-solving are not biologically determined while possibly influenced by the combined impact of many different factors that have biologogical, psychological and environmental origins' (p. 199). He suggests that the different patterns of mathematical problem-solving used by females and males can be traced back to the very early phase of elementary schooling.

I believe that my study is justified by the fact that, after an extensive search in literature, I could not find research on the problem-solving proficiency of Quantitative Techniques students. Research does not show a clear indication whether Age plays a role in problem-solving proficiency or not, therefore, I would like to include this aspect in my study. Much research is published about problem-solving skills, abilities, competencies, proficiencies and Mathematics, but as I could not find studies on the Mathematics background of particular problem solvers, e.g. did they take Mathematics, Mathematics Literacy or neither at secondary school in Grade 12, the Mathematics background of problem-solvers warrants attention. Not all studies found that Mathematics is an important predictor for success in Statistics, which includes Quantitative Techniques, so it would be interesting to learn what the situation at WSU would be. With reference to Gender difference in problem-solving skills, research seems inconclusive.

2.4 Conceptual framework

This study has been conceptualised around the view that the students' problem-solving proficiency (PSP) is better determined using an information processing approach rather than scrutinising skills involved in problem-solving. As indicated in 2.1, an information processing approach will enable the identification of problem areas found in problem-solving and how these areas can be improved.

Polya's problem-solving model is selected as an appropriate model to measure students' problem-solving proficiency. This is based on the fact that the model appears to be a base for other problem-solving models, as evidenced by the numerous problem-solving models encountered in literature and which seemed to have been modeled on Polya's problem-solving model. It is my view that Polya's model, as unravelled below, would provide a profound analysis of students' PSP. The four stages of Polya's problem-solving model are:

1. Understand the problem, i.e.
    - State the problem in your own words.
    - Identify the problem.
    - Name the unknowns.
    - Recognise available information about the problem.
    - Spot missing information.
2. Devise a plan by finding a connection between the data and the unknown, i.e.
    - Look for a pattern.
    - Study a similar problem.
    - Study related problems.
    - Write down a table, diagram or equation to represent the problem.
    - Identify subgoals.
3. Carry out the plan, i.e.
    - Implement plan devised in Stage 2.
    - Check each step when executing the plan.
    - Keep an accurate record of work.
4. Look back and check, i.e.
    - Check the results.
    - Interpret the answer in terms of the stated problem and make sure that it does make sense.
    - Establish if there is another method to solve the problem.
    - Determine if this result or technique will work for other related or more general problems (1945).

Models such as Polya's end with a very important component of problem-solving, i.e. looking back. The problem-solver has to reflect on how the problem was solved, decide if the strategies used were the best or, whether, and how, they can be improved. Collins, Brown and Holum (1991) agree with Schoenfeld (1985) that the reflection or 'abstracted replay' is of major value in solving problems. Students should step back and reflect on how they actually solved the problem and decide whether the particular set of strategies they used were the best possible and how they could be improved on.

Evidently each stage of the model has a number of aspects that clearly indicate the cognitive and metacognitive skills involved in problem-solving. These are skills that I consider pivotal in problem-solving. I, therefore, contend that Polya's model can be helpful in exploring the state of PSP of the Quantitative Techniques students.

The heuristic strategies for each stage of Polya's process engage cognitive skills, e.g.

> Understanding → focusing on the unknown, on the data,
> drawing a diagram, etc.
> Devising a plan → exploiting related problems, analogous
> problems, working backwards, etc.
> (Schoenfeld, 1987, p. 284).

Hill (1997) made use of the seventeen mental processes used by practicing technologists, indentified by Halfin in 1973, to construct an assessment tool. These mental processes include, amongst others, cognitive skills such as visualising, analysing, constructing models, testing, planning, organising, directing, co-ordinating, etc., i.e. all cognitive skills required to apply Polya's model. By using Polya's model to assess PSP, these underlying cognitive skills are measured indirectly.

Polya's model also involves metacognitive skills, such as the intelligent structuring and storage of input, search and retrieval operations and knowledge and monitoring of these processes which are fundamental to successful problem-solving. Researchers such as Schoenfeld (1987b) identified metacognition as a key factor in the process of problem-solving. It was also confirmed with a study by Gartman and Freiberg (1995) and Biryukov (2004).

The PSP of the Quantitative Techniques students will, therefore, be analysed according to the four stages of problem-solving identified by Polya, i.e. understand the problem, devise a plan, carry out the plan and interpret the result. Assessment of their proficiencies will be made by grading each problem-solving stage in a written test. All cognitive and metacognitive processes involved in solving the Quantitative Techniques problems will determine the PSP of a particular student.

CHAPTER 3

METHODOLOGY

3.1 Research Design

The research design for this study is a descriptive survey. Cresswell (2012) indicated that a descriptive survey design is appropriate for a study whose interest is a description of trends in an activity or process. In this study, my interest is in investigating the problem-solving proficiency (PSP) of students in a course, Quantitative Techniques, using a quantitative approach. The nature of my study necessitates a descriptive survey design where the participants will be required, firstly, to complete a questionnaire to provide demographic information and data about their highest Mathematics achievement. Secondly, students will write a pen and paper test to measure their PSP. The collected data would then be quantified and statistically analysed to determine the meaning and trends about the answers and responses provided by the participants.

3.2 Population

Quantitative Techniques is a compulsory second-year course for the National Diploma in Marketing programme at WSU. Sampling did not take place since the entire population of 129 students enrolled in the course in the year of the study was included in the study to maximise the quality of the data. I found including the population appropriate and plausible for the purpose of the study. Using the population also excluded any bias of the estimates.

3.3 Instrumentation

3.3.1 Identifying data collection instruments for the study

Garfield and Ben-Zvi (2007) stress the need for assessments that evaluate the students' understanding, not only procedural knowledge, which is a vital part of teaching and learning. This means that data about students' understanding must be collected, assessed and analysed to be useful for teaching and learning. There are various techniques to gather data, for example, questionnaires, observation schedules, interviews, tests and reviews, to name a few.

Questionnaires are the most widely used data collection technique in educational research (Radhakrishna, 2007). They are a cost-effective method to collect data from a large number of participants in a standardised way (Strange, Forest, Oakley, & The-Ripple-Study-Team, 2003). I, therefore, have decided to use a questionnaire to collect demographic data and information about the mathematical background of the Quantitative Techniques students. The participants' Mathematics background forms the foundation for Quantitative Techniques, which is not a school subject. A questionnaire, used to collect the demographic information in a study to predict students' performance in Mathematics and Science in Mpumalanga, was adapted for the use of this study (Maree, Aldous, Hattingh, Swanepoel, & Van der Linde, 2006). See appendix A for the questionnaire.

Following what was discussed in Section 1.5.5, it should also be pointed out that the Quantitative Techniques course consists of two modules. Module I, offered during the first semester of each year, deals mostly with content knowledge and routine calculations. It does not present many options to evaluate PSP. Conversely, the study material in Module II, which is offered in the second semester, presents several options to evaluate PSP in terms of the variety of topics and techniques covered.

Various methods of data collection were possible but mostly not cost effective and time effective. A homework exercise or an assignment was considered inappropriate to evaluate PSP because participants could work together or copy work from each other. Such an instrument would, therefore, not give a true reflection of the individual participants' PSP.

Examination scripts as a form of data collection had to be excluded due to the fact that only participants with a semester mark of 40% and above are allowed to write the examination. Based on past records it is known that there is a chance that some lower performing students might not achieve 40% to be allowed to write the examination, which would exclude the low performing students from the study. In turn, this could affect the credibility of the study. Garfield and Ben-Zvi (2007) point out that the use of the final examination result to measure the outcome is problematic if it is used without establishing evidence of validity and reliability. Examination scripts were then discarded as a source of data on the PSP of all the registered Quantitative Techniques students.

Interviews were also ruled out because of the logistics involved, i.e. the time the organisation of such an exercise would have taken and the little time available for interviewing all participants at the end of the semester. Quantitative Techniques students attend lectures on two campuses, 40 km apart and the lecturer (the researcher in this case) has to travel between campuses to lecture this subject, besides teaching other Mathematics courses. Together with the packed syllabus of Module II, offered during the second semester, there was no time to interview students before the end of the academic activities of the year.

The possibility of using multiple-choice questions to evaluate PSP was investigated. The use of multiple-choice tests to measure thinking was criticised in most literature reviewed. ‘Multiple-choice tests are ill suited for assessing productive thinking and problem-solving skills that often constitute important objectives of education’ (Jones, 1988, p. 233). Tiller (2007) argues in favour of multiple-choice questions, but warns that consistency is often a problem when grading open-ended tests, even with a test rubric. He refers to Lambert and Lines (2000) who argue that multiple-choice tests are the preferred method of assessment because they are easy, cheap and quick to grade and that these tests have a high reliability, but are often not valid. Haladyna, Downing and Rodriguez (2002) assert that multiple-choice questions measured content effectively, but that there are limitations with the measurement of higher levels of thinking.

Some studies where multiple-choice questions were used were reviewed. Marriott, et al. (2009) employed an online multiple-choice format to assess students’ statistical problem-solving in Grade Five and Grade Six classes. Latterell (2003) tested secondary school students’ problem-solving skills in Mathematics by using multiple choice questions as well as constructed response questions. On the contrary, Wu and Adams (2006) felt that multiple choice questions could not capture all the relevant information and designed a test, seventyfive percent of which comprised of open-ended questions which were scored. These are examples of studies on problem-solving skills, abilities or proficiencies, and the focus of these studies was on primary and secondary education. Seemingly, there is a dearth of literature on the use of multiple-choice questions to assess PSP in tertiary institutions. It is against this background that a compulsory, written semester test was found to be the most suitable instrument to record students' PSP at WSU. Thus the second instrument used to collect data in this study was a written test (See Appendix B).

Data collection instruments suitable for this study were, firstly, a questionnaire and secondly a written test. Thirdly, a scoring template was used as an instrument to evaluate students' PSP (See Appendix C).

3.3.2 Development of data collection instruments

The development of the three instruments used for the collection of data in this study follows.

3.3.2.1 Questionnaire.

The questionnaire was based on a questionnaire used by Maree, Aldous, Hattingh, Swanepoel and Van der Linde (2006) in a study to predict student performance in Mathematics and Science in Mpumalanga. Maree et al.'s (2006) questionnaire was adjusted to collect data for this study. Section A of Maree's questionnaire collects background information, but was designed for students taking Mathematics and Science in secondary schools. This section was adjusted to exclude irrelevant background information and to include the collection of information relevant to the study of the problem-solving proficiency (PSP) of the participants in this study, i.e. students' Age, their performance in Mathematics in Grade 12, whether they had Data Handling training at school or not and the Gender of students participating in the current study. The background information collected for this study is consistent with previous studies in Statistics and other related fields (e.g. Utts, Sommer, Acredolo, Maher, & Matthews, 2003; Maree, Aldous, Hattingh, Swanepoel, & Van der Linde, 2006). The participants also had to provide their contact numbers in case unclear information provided had to be clarified (See Appendix A).

3.3.2.2 Written test.

A compulsory pen and paper test was used to determine participants' PSP. This test covered 90% of the topics taught during the second semester. The other 10% of the syllabus was taught after data collection took place and could, therefore, not be included in the test. The topics are: Estimation (Question 1), Hypothesis Testing (Questions 2 and 3), Index Numbers (Question 4) and Regression Analysis (Question 5). Evidently each topic was assigned a question except Hypothesis Testing which was assigned two questions (See Appendix B). To determine a participant's confidence level (PCL) in his or her solutions, he or she had to rate a solution as incorrect, partially correct or correct at the end of each question. This was done to include, together with Mathematics performance, Gender etc., another confounding variable in this study. This approach was also followed by researchers such as Utts, et al. (2003), Johnson & Kuennen (2006) and Potgieter, Harding and Engelbrecht (2008). See Appendix B for the written test.

3.3.3 Development of the data scoring template

A problem solving proficiency scoring template was modeled on Polya's problem-solving model. An assessment framework was formulated for each question in the written test, based on Polya's model for problem-solving. Each stage in Polya's model was regarded as a level of PSP:

i. Level 1 (P1): the lowest level of problem-solving according to Polya. It determines whether a participant has understood the problem. That is, can the participant identify the problem, name the unknowns, recognise the given information about the problem and identify missing information.
ii. Level 2 (P2): Determine whether a participant can devise a plan by finding a connection between the given information and the unknown. That is, can a participant identify a pattern, study a similar problem, study related problems, write down a table, diagram or equation to represent the problem and identify sub-goals.
iii. Level 3 (P3): Determine whether a participant can carry out the plan. That is, can a participant implement the plan devised in P2, check each step when executing the plan and keep an accurate record of this work.
iv. Level 4 (P4): This is the highest level of the model. This level determines whether a participant can verify the results, interpret their answer in terms of the stated problem and make sure that it makes sense. Also, can participants establish whether there was an alternative method to be used to solve the problem and determine if such a result or technique could work for other related or more general problems?

Each of the four levels of problem-solving, for each problem, was scored as follows:

2 $\Rightarrow$ fully proficient

1 $\Rightarrow$ partially proficient

0 $\Rightarrow$ not proficient

9 $\Rightarrow$ no attempt

All instruments were tested in a pilot study to iron out problems that might occur with the data collection. See Appendix C for the scoring template.

3.3.4 Validity and Reliability

3.3.4.1 Validity.

The instruments were content validated by two experts in Statistics and three experts in Statistics Education. They specifically checked whether all topics in the syllabus were accordingly tested. Discussions with all the experts ensued so as to seek clarity about the suggestions and comments they had made about the instruments.

Mathematics performance is strongly related to performance in reading comprehension (Vilenius-Tuohimaa, Aunola, & Nurmi, 2008). Although reading skills could have affected the results of a test such as the written test, their effect was assumed to be minimal since participants wrote the test almost at the end of the academic year and they would, by then, have been familiar with the vocabulary used in the test. Participants' PSP was evaluated in five different questions to maximise content validity.

In an attempt to establish validity, the results of the current study were compared with the results of a study by Zakaria and Yusoff (2009), who studied the problem-solving skills of students of Algebra at a matriculation college in Malaysia. Figure 3 compares the mean performance in each level of the two studies.

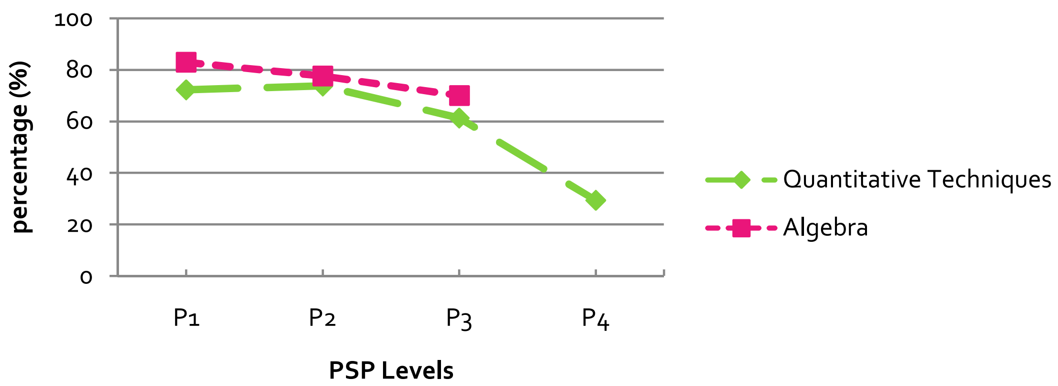


Figure 3. Comparison of mean PSP performances in Quantitative Techniques and problem-solving skills in Algebra.

Although the model Zakaria and Yusoff used did not have a phase for interpreting results, the trend for the first three phases of Polya's model used in the current study compares well with the results found by Zakaria and Yusoff, even if it is on a lower level.

Pearson Product Moment Correlations (Table 3) for the main study were calculated to determine whether PSP is related to participants' Test Marks.

Table 3. *Pearson Product Moment Correlation (r) between Test Marks and PSP levels*

PSP level	***r***
P1	0,780
P2	0,856
P3	0,876
P4	0,756

Note. n = 128

The Pearson Product Moment Correlations (r) (Table 3) indicate that there is a high correlation between Test Marks and PSP. r is statistically significant if $|r| > 0{,}198$ for n = 128 and practically significant if $|r| > 0{,}3$. This result agrees Omiwale's (2011) finding that students with better problem-solving abilities achieve better in Physics.

Chi^2-tests, a statistical analysis used to determine whether there is a significant association between two variables, indicated a statistically significant relationship between Test Marks and PSP levels ($p < 0{,}0005$). Cramèr's V, a statistical measure for the association between two variables, was large in all cases, i.e. the Chi^2-tests confirmed practical significance.

The relationship between PSP and participant confidence level (PCL) was investigated. Chi^2-tests were carried out to establish if a relationship exists between participants' PSP and PCL. These tests revealed that the relationship between PCL and PSP levels is statistically significant ($p < 0{,}0005$). Cramèrs' V (medium) confirmed these findings. The strong relationships between participants' PSP and Test Marks and PSP and PCL point toward predictive validity.

Consequential validity deals with the impact of a test on, amongst others, teaching and learning (Messick, 1994). This view is supported by McGaw (2006) who, in his keynote address at the 32rd IAEA conference in Singapore, warned against misdirected effort and teaching 'outcomes that can be measured rather than those that are important'. An effort was, therefore, made in this study to ensure the validity of the test by eliminating negative consequences, i.e. care was taken to give the participants clear directions for the assessment test, the test language was the same as the language in which they received tuition, test procedures that are well-known to participants were followed, invigilators were present during the test to prevent cheating and a scoring template was designed to prevent inconsistent and subjective scoring by the marker and the moderator. These measures, together with the correlations discussed above, suggest that the test can be used to identify a profile of students' PSP, which could indicate the need for intervention.

Results of the current study were compared to findings by Marriott, Davies and Gibson (2009) to establish validity. See Figure 4. Although Marriott et al. studied school learners' PSP in Data Handling and their performance was on a lower level than the findings of the current study, the PSP trends in the first three levels of these two studies compare well.

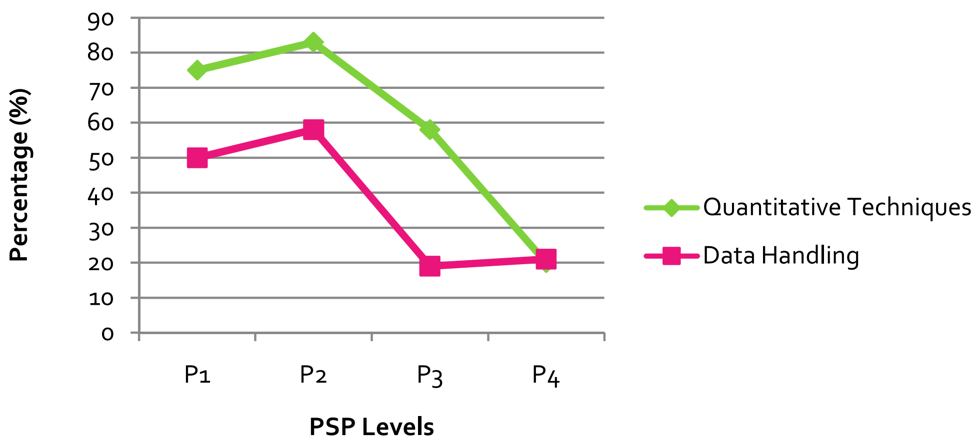


Figure 4. Comparison of median PSP performances in Quantitative Techniques and Data Handling.

The above discussion supports the conclusion that the instruments are considered valid for the study. Content validity was ensured by a thorough literature study, the pilot study, views of the experts, the fact that no sampling took place and the fact that participants were tested on ninety percent of the Quantitative Techniques syllabus. Much care was given to eliminate negative consequences. Validity was confirmed by comparing PSP results of this study with findings of the study of problem-solving and Data handling of school learners by Marriott et al. Findings of this study also agree with the results of the study of problem-solving skills of students of Algebra at a matriculation college in Malaysia. The high correlations between Test Marks and PSP, as well as between PCL and PSP, indicate predictive validity.

3.3.4.2 Reliability.

Reliability refers to the consistency of measurement outcomes and the extent to which they are accurate, error free and stable (Gaberson, 1997). Kimberlin and Almut agree with this view on the reliability of measurement instruments in research (2008). In quantitative research, reliability also assures the possibility of replication (Oluwatayo, 2012). Attention was paid to ensure that the measurement outcomes of this research were consistent, accurate, error free and stable. The researcher has a B.Sc.(Hons) Mathematical Statistics degree and more than 15 years of experience in teaching Statistics and Mathematics. She is, therefore, knowledgeable about the subject, knew the participants well and was familiar with their environment. No other people were involved in the research, which should reduce researcher effects (Mouton & Marais, 1996). The researcher had a good relationship with the participants, which reduced possible negative researcher effects. To control context effects she explained the purpose of the study before the data was collected (Mouton & Marais, 1996). A neutral setting, the lecture hall where the students regularly attended Quantitative Techniques lectures, was used for the collection of the data (Mouton & Marais, 1996). The test was administered at the end of the year, which means that the students were familiar with the surroundings, people involved and procedures.

The questionnaire used by Maree, et al. (2006) was adjusted to collect information about the participants' demographic information as well as their mathematical background to ensure the reliability of the instrument. The questionnaire was filled in at the beginning of the test after the purpose of the study was explained to the participants. In a further attempt to ensure reliability, participants were contacted when information was missing and the missing data filled in. Five different topics were tested in the written test to establish participants' PSP to maximise the reliability of the results (Gaberson, 1997).

Subjectivity was minimised to ensure inter-rater reliability. The marker and moderator used the same scoring template to mark the assessment tests and rate participants' PSP. The Pearson Product Moment Correlation between the marker and moderator was 0,970. Inter-rater reliability is illustrated in Figure 5, which compares the PSP scores of the marker and moderator. On average 92% of scores were the same, 5% of the moderator's scores were lower than the marker's scores and 3% higher than the marker's scores. A high inter-rater reliability was achieved.

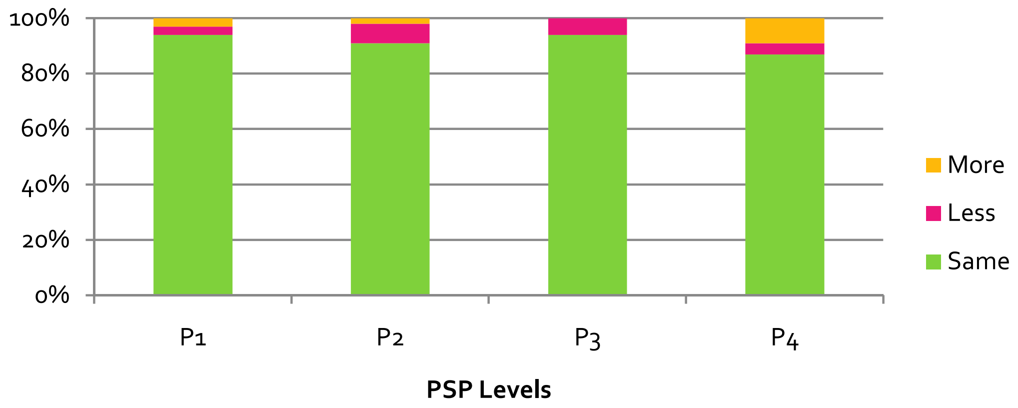


Figure 5. Comparing the moderator scores with the marker's scores.

In a pilot study data was collected data from second year engineering students on a module of Statistics they take, which covers the same Statistics topics as was used in the main study on Quantitative Techniques students. Problems were ironed out before the data collection for the main study took place. Since data was collected from participants in the main study at the end of the semester, there was no time for retesting. Parallel tests could not be done as this course is taken by no other students at this university.

The most familiar tests for internal consistency reliability are the Spearman-Brown prophecy formula, Kuder-Richardson formulas 20 (K-R20) and 21 (K-R21) and Cronbach's alpha. The Spearman-Brown prophecy formula is used to estimate the ideal number of test items when designing a test, i.e. before all test items are available. K-R20 and Cronbach's alpha are the most frequently reported estimates for internal consistency, which is a measure based on correlations between different test items on the same test. K-R20 can only be applied if the test items are scored dichotomously. Cronbach's (1951) alpha co-efficient is conceptually related to the Spearman-Brown prophecy formula (Sijtsma, 2009). Cronbach's alpha co-efficient is recommended as measure for internal consistency when test items in a study have more than two possible scores (Wells & Wollack, 2003; Gay, Mills & Airasian, 2006; Sun, Chou, Stacy, Ma, Unger & Gallaher, 2007). It was decided to use this co-efficient to measure the reliability of the instrument because, since it partly depends on the number of test items (more test items increase Cronbach's alpha co-efficient), it provides a lower-bound estimate of the true reliability (Traub, 1994 in Mugisha, 2012; Sun, Chou, Stacy, Ma, Unger & Gallaher, 2007). Cronbach's alpha co-efficient was also recommended by a statistical consultant as a measure of internal consistency because in this study all tests items are known (Table 4). George and Mallery (2003, p. 231) provide the following rule of thumb for Cronbach's alpha co-efficient: '$\alpha > 0{,}9$ – Excellent, $\alpha > 0{,}8$ – Good, $\alpha > 0{,}7$ – Acceptable, $\alpha > 0{,}6$ – Questionable, $\alpha > 0{,}5$ – Poor, and $\alpha < 0{,}5$ – Unacceptable'.

Table 4. *Cronbach's Alpha (α)*

Score	**α**
Test Marks	0,74
PCL	0,82
P1	0,59
P2	0,64
P3	0,68
P4	0,66

Cronbach's alpha was used to examine the reliability of PSP score by comparing them to other measures of performance, i.e. Test Marks and the participants' view of their performance (PCL) (See Table 4). Cronbach's Alpha indicates, on average, an acceptable internal consistency. This result agrees with findings by Johnson and Kuennen (2006) who analysed students' basic Mathematics skills. Results of the current study suggest that the PSP performance is largely consistent with other measures of student performance and can, therefore, be taken as a reliable measure of the participants' problem-solving proficiency.

Reliable demographic data was collected and participants were tested with multiple questions on ninety percent of the study material of the Quantitative Techniques course. The last ten percent of the syllabus was taught after the written test for this research. Another assessment could not be done in the limited time before the final examination.

3.4 Data Collection

Data collection took place towards the end of the semester. In the test participants had to complete the questionnaire for collection of demographic information and information about their Mathematics background and do the written test to access their PSP. I decided to collect the demographic information on the day the test was written to ensure that the relevant information could be collected from all the participants. Past records showed that there was never a 100% attendance on any other day, which would complicate the effort to collect the demographic information. The aim of the research was explained to the participants and each participant gave written permission that his or her test could be used in the study. Participants were allowed ten minutes to fill out the questionnaire and eighty minutes to write the test. In fact, the pen and paper test used in the study also served as a semester test that is an integral part of the continuous assessment of the course. At the end of each question participants were asked to rate their own performance in that particular question. The data collection took place under normal test conditions, i.e. invigilators were present and participants were not allowed to discuss questions or have any notes or reference material with them but were allowed to use non-programmable pocket calculators. Answers for the test questions were written in the spaces provided for answers on the question paper.

3.5 Ethics

I realise that I am accountable to society for the integrity of my research in terms of what is reported and how I obtained my information (Babbie & Mouton, 2001). As an academic staff member I am well aware of plagiarism and the law on copyright and, therefore, undertook to adhere to these laws at all times. I have acknowledged and cited each source used during this research in the reference list. I am also aware of the danger of research fraud and, therefore, used only the data obtained by means of the questionnaire and written test for analysis (See Appendix B).

Permission for the study was given by the Directorate of Research Development of WSU. Assurance was given that the research would not have a negative impact on the work schedule or any participant. Although the university and course used for the study was disclosed, the year in which the data collection took place was not mentioned.

The purpose of the research was explained to all participants. Participants gave written consent that their tests could be used in the study (See Appendix B). They were assured of strict confidentiality and anonymity. The identity of the participants was obscured by using only the test scores for statistical analysis with no reference, such as the student numbers, codes or names, to individuals. The respondents and records will remain protected once the research has been completed. It will be destroyed after five years.

CHAPTER 4

DATA ANALYSIS

4.1 Problem-solving proficiency (PSP) scoring

Participants' test scripts were scored by a marker and moderator according to the four stages of Polya's problem-solving model (See Section 3.3.2). The following marks were allocated (See Appendix C for the scoring template):

- 2 marks for a correct answer
- 1 mark for a partially correct answer
- 0 for an incorrect answer
- 9 for no attempt

The data analysis will now be discussed per research question.

4.2 Research Question 1

What is the level of problem-solving proficiency (PSP) of Quantitative Techniques students at WSU?

The participants wrote a compulsory test and had to answer all the questions. Descriptive Statistics for the level of PSP were calculated as shown in Table 5.

Table 5. *Descriptive Statistics for level of PSP*

Percentage (%)	Mean	*SD*	Minimum	Quartile 1	Median	Quartile 3	Maximum
P1 Score	72,29	19,24	8,33	58,33	75,00	83,33	100,00
P2 Score	73,77	23,60	0,00	58,33	83,33	91,67	100,00
P3 Score	61,30	26,12	0,00	41,67	58,33	83,33	100,00
P4 Score	29,38	25,09	0,00	10,00	20,00	40,00	100,00
Test Mark	53,02	22,34	0,00	38,00	53,00	72,00	94,00
PCL Score	52,78	29,93	0,00	33,33	58,33	75,00	100,00

Notes. SD = Standard Deviation; PCL = participants' confidence level

The mean, standard deviation (*SD*), median and quartiles were determined for each level of problem-solving (P1, P2, P3 and P4), test mark and participants' confidence level (PCL).

Figure *6* gives a visual comparison of the means scores of the four PSP levels.

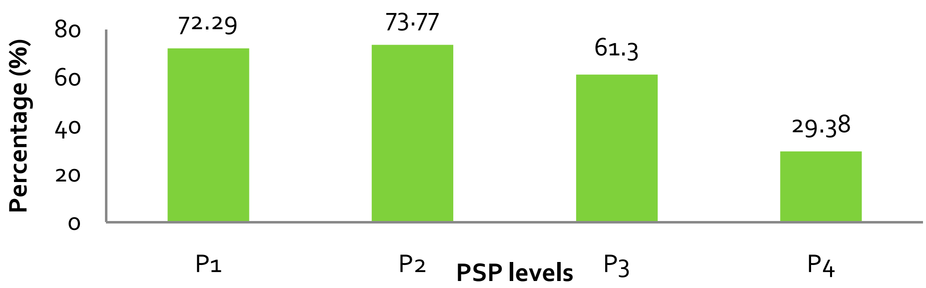


Figure 6. Comparison of mean scores of PSP levels.

From this display it is clear how the average level of PSP decreased from the lowest level of PSP (P1) to the highest level of PSP (P4). The poor performance in P4 is highlighted by the fact that the median for interpretation of the results is only 20% (See Table 5). Participants scored an overall average of 59,19% for level of PSP. The standard deviation, minimum and maximum values, quartiles and median give an indication of the spread of the data about the mean. These results show that the data is not clustered closely about the means. It is also interesting to note the close result of the participants' test mark and the confidence level in their answers.

Figure 7 is a graphic display of how participants performed in each PSP level with regards to whether they did not make an attempt to solve a problem, solved it incorrectly, partially correct or correctly.

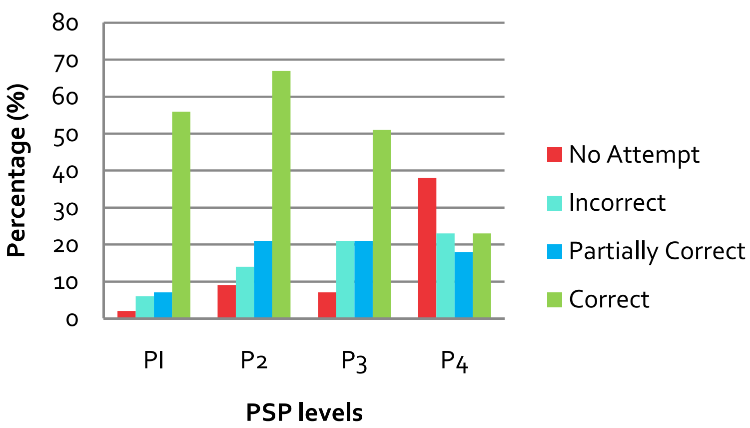
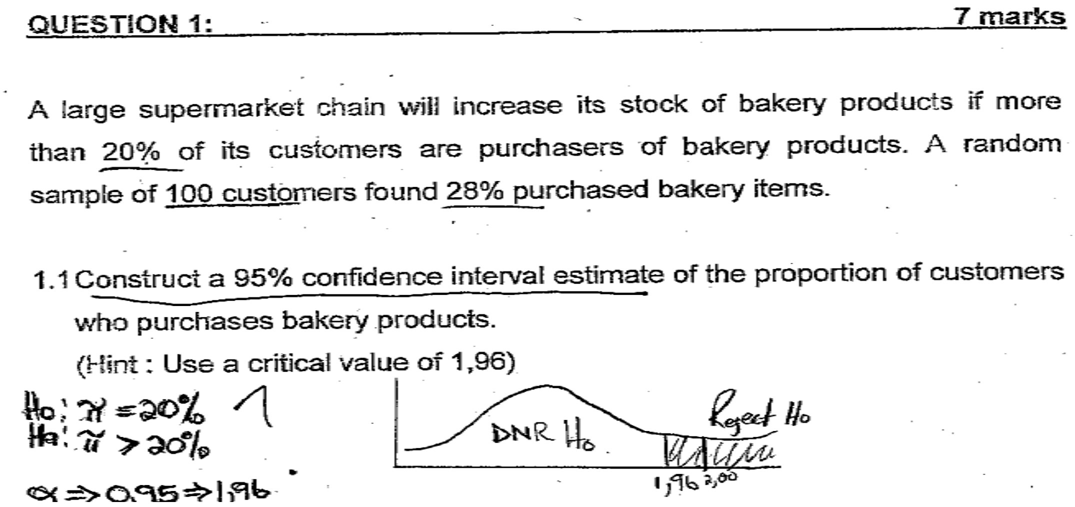


Figure 7. Performance of participants on each PSP level.

When a participant did not make an attempt to execute a specific level of solving the problem, i.e. the space for the answer was left blank, a 9 was scored. Figure 8 is an example of an incorrect answer. The problem is solved by calculating a confidence interval, but the participant attempted to perform a hypothesis test. This is incorrect and the score is 0.



QUESTION 1: **7 marks**

A large supermarket chain will increase its stock of bakery products if more than 20% of its customers are purchasers of bakery products. A random sample of 100 customers found 28% purchased bakery items.

1.1 Construct a 95% confidence interval estimate of the proportion of customers who purchases bakery products.
(Hint : Use a critical value of 1,96)

$H_0: \pi = 20\%$
$H_a: \pi > 20\%$
$\alpha \Rightarrow 0.95 \Rightarrow 1,96$

Figure 8. Incorrect answer.

Figure 9 is an example of a partially correct answer. The participant understood that the independence of association of the variables ‘Personality Type’ and ‘Colour of preference’ must be tested in Question 2, but wrote the hypothesis down incorrectly. A 1 was scored.

10

QUESTION 2 : **11 marks**

A market researcher would like to know if there is a relationship between personality type and colour. A sample of 50 people is used to record personality and colour preference. Results are given in the table below :

	COLOUR		
PERSONALITY TYPE	Blue	Red	Yellow
Extroverted	5	20	5
Introverted	10	5	5

Test at a significance level of 5% if there is a relationship between personality type and colour preference.

Ho : Personality type and Colour are related. X

Ha : personality type and Colour are independent.

Figure 9. Partially correct answer.

A participant who indicated that the solution of Question 2 is a hypothesis test for independence of association of the variables ‘Personality Type’ and ‘Colour of preference’ and stated the hypothesis correctly was correct and scored 2 (Figure 10).

a

QUESTION 2 : **11 marks**

A market researcher would like to know if there is a relationship between personality type and colour. A sample of 50 people is used to record personality and colour preference. Results are given in the table below :

	COLOUR			
PERSONALITY TYPE	Blue	Red	Yellow	
Extroverted	5	20	5	30
Introverted	10	5	5	20
	15	25	10	50

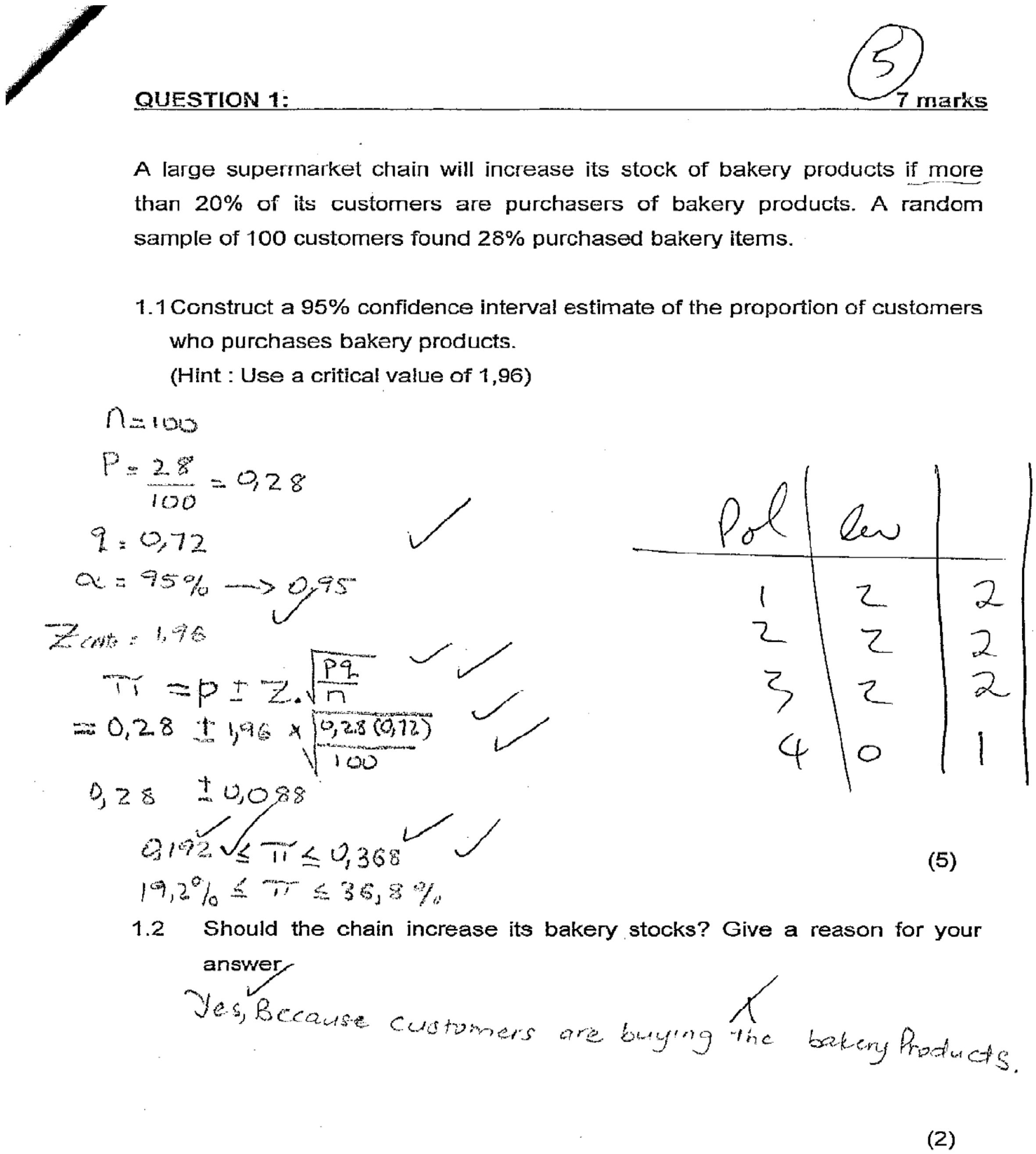
Test at a significance level of 5% if there is a relationship between personality type and colour preference.

H_0 : Personality type and colour are independent

H_a : Personality type and colour are Associated

Figure 10. Correct answer

On average more than 50% of participants could complete the first three stages of problem-solving successfully. Figure 11 is an example of a participant who completed the first three levels of solving the problem in Question 1 successfully. The table inserted next to the participant's answer reflects the assessment according to Polya's model (column 1) by the marker (column 2) and the moderator (column 3).



QUESTION 1: 5 7 marks

A large supermarket chain will increase its stock of bakery products if more than 20% of its customers are purchasers of bakery products. A random sample of 100 customers found 28% purchased bakery items.

1.1 Construct a 95% confidence interval estimate of the proportion of customers who purchases bakery products.
(Hint : Use a critical value of 1,96)

$n = 100$
$P = \frac{28}{100} = 0{,}28$
$q = 0{,}72$
$\alpha = 95\% \rightarrow 0{,}95$
$Z_{crit} = 1{,}96$
$\pi = p \pm Z.\sqrt{\frac{pq}{n}}$
$= 0{,}28 \pm 1{,}96 \times \sqrt{\frac{0{,}28\,(0{,}72)}{100}}$
$0{,}28 \pm 0{,}088$
$0{,}192 \leq \pi \leq 0{,}368$
$19{,}2\% \leq \pi \leq 36{,}8\%$

Pol	Lev	
1	2	2
2	2	2
3	2	2
4	0	1

(5)

1.2 Should the chain increase its bakery stocks? Give a reason for your answer.

Yes, Because customers are buying the bakery Products.

(2)

Figure 11. Successful completion of the first three stages of problem-solving.

The participant displayed an understanding of the problem (P1) by correctly selecting a procedure to calculate a confidence interval, as well as correct identification of the parameters (n = 100; p = 0,28; α = 0,05 ⇒ Z_{crit} = 1,96). The participant selected the correct procedure (P2), i.e.$p \pm Z.\sqrt{\frac{pq}{n}}$, to solve the problem and then executed the procedure correctly (P3), i.e. $0{,}28 \pm 1{,}96.\sqrt{\frac{0{,}28(0{,}72)}{100}} \quad \Rightarrow \quad 19{,}2\% < \pi < 36{,}8\%$. The results were interpreted as partially correct, i.e. the correct conclusion was made but a wrong reason was given.

The data also indicates that participants found P4 challenging. More than a third of the participants did not even attempt this stage, i.e. no attempt was made to interpret their findings and just over 20% could complete this stage of problem-solving successfully. The poor performance in P4 is highlighted by the fact that the median for interpretation of the results is only 20% (Table 5).

The percentage of participants who made no attempt (except for P3) and those who performed a specific stage incorrectly increased from P1 to P4, i.e. they found it more and more difficult. The decreasing PSP trend from P2 to P4 for participants who could carry out the level correctly indicates how participants' PSP decreased from the lower level of problem-solving to the higher level of problem-solving. This is supported by the mean score in each level of PSP (See Table 5 on p. 67). In P3 the lower value for *no attempt* indicates that more participants made an attempt to execute the plan.

The frequency distributions calculated for each of the four PSP levels are given in Table 6.

Table 6. *Frequency distributions of PSP levels (%)*

Achievement intervals	**[0 to 20)**		**[20 to 40)**		**[40 to 60)**		**[60 to 80)**		**[80 to 100]**	
	N	%	N	%	N	%	N	%	N	%
P1 Score	1	1%	6	5%	27	21%	39	30%	56	43%
P2 Score	3	2%	9	7%	26	20%	26	20%	65	50%
P3 Score	8	6%	19	15%	38	29%	22	17%	42	33%
P4 Score	44	34%	39	30%	26	20%	11	9%	9	7%

Note. N = number of participants

The graphical display of this data in Figure 12 illustrates the frequency distributions of PSP scores.

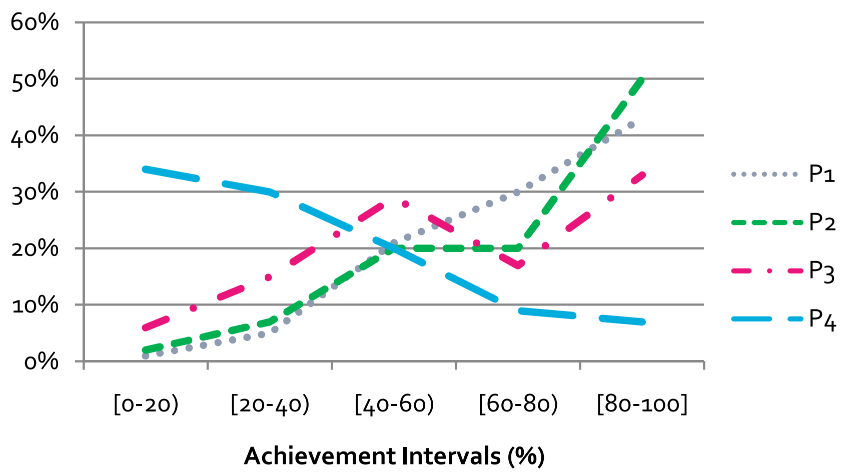


Figure 12. Frequency Distributions of PSP scores.

For P1, P2 and P3 between 1% and 6% of participants achieved below 20%. This gradually increased to between 33% and 50% for participants who scored above 80%. Positive trends exist for PSP in P1, P2 and P3 over the intervals. The inverse is true of P4, i.e. the P4 score is 34% for participants who scored below 20% for P4 and 7% for those who scored above 80% for P4. There is, therefore, a negative trend for P4. This emphasises the poor performance in P4.

The Pearson Product Moment Correlation Coefficient is a measure of the linear dependence of two variables, giving a value between +1 (total positive correlation) and -1 (total negative correlation). A coefficient of 0 indicates no correlation between the variables. The Pearson's Product Moment Correlations among problem-solving proficiency levels are listed in Table 7.

Table 7. *Pearson Product Moment Correlations (r) among Problem-Solving Proficiencies*

Variable 1	**Variable 2**	***r***
P1 Score	P2 Score	0,832
P1 Score	P3 Score	0,702
P1 Score	P4 Score	0,531
P2 Score	P3 Score	0,847
P2 Score	P4 Score	0,563
P3 Score	P4 Score	0,649

The Pearson's Product Moment Correlations r in Table 7 show that there is a strong association among the PSP levels. r is statistically significant ($p < 0{,}05$) if $|r| > 0{,}197$ for $n = 129$ and practically significant if $|r| > 0{,}30$. Statistical significance refers to the difference among areas that are compared and practical significance reasons whether or not the difference in statistical significance is enough to make a difference in the overall scheme.

This study did not investigate the nature of these associations. In this context it means that there is some association between the variables, i.e. if a participant is proficient in one PSP level, he or she might also possibly be proficient in the other PSP levels as well.

To confirm these findings, statistical and practical significance were evaluated for the associations between the PSP levels. Statistical and practical significance of the associations between the PSP levels would indicate an association between the particular proficiency levels. Chi^2–tests determined the statistical significance ($p < 0{,}05$) of associations between the PSP levels. Cramer's V statistic was calculated to determine practical significance for the PSP levels. Cramer's V statistic is used to measure association between two nominal variables, giving a value between 0 and +1 (inclusive), where 0,10 and less indicates a very weak, if any, association, 0,10 to 0,20 a weak association, 0,20 to 0,30 a moderate association and above 0,30 a strong association. Results are summarised in Table 8.

These results indicate an association between P1 (understanding the problem) and P2 (make a plan), P1 (understanding the problem) and P3 (execute the plan), P2 (make a plan) and P3 (execute the plan) and P3 (execute the plan) and P4 (look back and check). The associations between P1 and P4 and P2 and P4 are neither statistically nor practically significant. Associations between some PSP levels are, therefore, confirmed.

Table 8. *Summary of Chi^2 – tests for associations between PSP levels*

PSP levels	**Chi²-value**	***df***	***n***	***p***	***V***
P1 and P2	60,64	4	129	< 0,0005	0,48
P1 and P3	31,40	4	129	< 0,0005	0,35
P1 and P4	5,88	4	129	0,208	below 0,10
P2 and P3	71,81	4	129	< 0,0005	0,52 Large
P2 and P4	7,70	4	129	0,103	below 0,10
P3 and P4	31,79	4	129	< 0,0005	0,35 Large

Note. df = degrees of freedom; *n* = sample size; *p* = statistical significance; *V* = Cramer's *V*

The first research question, i.e. *What is the level of problem-solving proficiency (PSP) of Quantitative Techniques students at WSU?*, can now be answered. A measure of the proficiency in each level of problem-solving has been calculated (See Table 5 on p. 67). The levels of PSP for Quantitative Techniques students are as follows:

- 72,29% understand the problem
- 73,77% can make a plan to solve the problem
- 61,39% can execute the plan
- 29,38% can interpret the results.

These levels indicate a big problem with proficiency in interpreting results (P4), which must be addressed by some intervention. Proficiency in the execution of the plan (P3) is also not high and needs intervention. The findings of the Pearson's Product Moment Correlations, Chi^2–tests and Cramer's *V*, i.e. the indications that there are associations between the levels of proficiencies, are encouraging and could be helpful in planning any future intervention to correct the problems. This means that by addressing and improving PSP in one of the levels of proficiency, it could have a positive effect on the other PSP levels, e.g. improved PSP in understanding a problem, could improve PSP in the other levels of problem-solving.

4.3 Research Question 2

What problem-solving weaknesses or strengths do Quantitative Techniques students at WSU display?

Problem-solving proficiency (PSP) strengths of participants lie in understanding a problem (P1) and making a plan (P2) (See Figure *6* on p. 67). The PSP performance in each level shows that for P1, P2 and P3 a low percentage of participants, i.e. 1% (P1), 2% (P2) and 6% (P3), scored below 10% (See Figure 12 on p. 74). The highest scores, i.e. above 80%, were achieved by 43% of participants for P1, 50% for P2 and 33% for P3. However, it should be pointed out that scores of 43%, 50% and 33% are not high. This illustration also shows that participants are weakest in interpreting the results (P4). This is where 34% (the majority) of participants scored below 20% and 7% of participants scored above 80%. Ideally, scores should be above 80% for all PSP levels.

Furthermore, differences between the consecutive PSP levels were ranked, one-sample *t*-tests were done to test statistical significance of the difference of PSP scores of the levels. Cohen's *d* Statistics, interpreted as the standardized difference between two means, were calculated to test the practical significance of differences of PSP scores of the levels. A significance level of 5% was used in all the analyses. Table 9 summarises the analyses of the differences between the PSP scores of the levels.

Table 9. *Statistics for differences between PSP scores of the PSP levels*

Variables	Variables		Mean		*SD*		Diff		Inference			
1	2	Rank	1	2	1	2	Mean	SD	*t*-value	*df*	*p*-value	Cohen's *d*
P2 Score	P1 Score	1	73,77	72,29	23,60	19,24	1,49	13,11	1,29	128	0,100	0,11
P2 Score	P3 Score	2	73,77	61,30	23,60	26,12	12,47	13,98	10,13	128	0,000	0,89
P3 Score	P4 Score	3	61,30	29,38	26,12	25,09	31,93	21,48	16,88	128	0,000	1,49

Notes. SD = standard deviation; Diff = difference between two variables; *df* = degrees of freedom

Table 9 shows that the *t*-values of the ranked mean difference between PSP levels increased from P1 to P4. This means that there are differences between the PSP levels and that participants' performance deteriorated from P1 to P4. The differences between the problem-solving levels are as follows:

P1 and P2 is 1,49%

P2 and P3 is 12,47%

P3 and P4 is 31,93%

PSP is highest for P1 (understanding a problem) and P2 (making a plan) where the proficiency difference is 1,49%. PSP for P3 (executing the plan) is weaker than that of P2 (making a plan) by 12,47%. Proficiency for P4 (interpreting the results) is weaker than proficiency for P3 (executing the plan) by an alarming 31,93%. This clearly highlights the problem area.

In Table 9, the one-sample *t*-tests revealed that the difference between P1 and P2 is not statistically significant (p = 0,1 > 0,05) nor practically significant (d = 0,11 < 0,2). This means that there is no difference between these two PSP levels in which participants achieved highest. Difference between P2 and P3 is statistically significant (p = 0,0 < 0,05) and practically significant (d = 0,89 > 0,2). The same applies to the difference between P3 and P4 (p = 0,0 < 0,05; d = 1,49 > 0,2). The *t*-values indicate that the difference between P3 and P4 is also bigger than the difference between P2 and P3. These results highlight the differences between the PSP levels P2, P3 and P4. It can be said that participants are most proficient and almost equally proficient in P1 and P2. It also indicates that participants performed second best in P3 and that P4 was the most challenging PSP level.

A ranking method based on *t*-tests with Bonferonni adjustment and Cohen's *d* Statistics was used to determine the differences between the PSP levels (Venter, 2006). In this ranking '1' indicates the highest position. The results have been summarised in Table 10 wherein the mean scores for each PSP level have been ranked. Both P1 and P2 have a ranking of 1 which indicates that there is no significant difference between these two levels. This means that participants achieved the highest in P1 and P2. A ranking of 2 for P3 indicates a lower PSP achievement than in P1 and P2. The ranking of 3, the lowest position in this ranking, for P4 indicates that participants achieved the lowest in P4, i.e. they are weakest in interpreting their results. The results of this ranking point out that there was little difference between P1 and P2. The participants' PSP is strongest in P1 and P2 since they have the highest ranking. PSP for P3 is weaker than P1 and P2 and participants' PSP is weakest in P4.

Confidence intervals were constructed to estimate the mean PSP score for each level (Table 10). All these mean scores fall in the 95% confidence interval for the particular PSP level. This means that the values are true reflections of the actual means of the PSP levels and are, therefore, good, i.e. with a confidence level of 95%, estimates of the mean PSP in each level of problem-solving.

Table 10. *Ranked Statistics*

Item	Rank	Mean	*SD*	95% Confidence Interval	
				Low	High
P2 Score	1	73,77	23,60	69,70	77,84
P1 Score	1	72,29	19,24	68,97	75,61
P3 Score	2	61,30	26,12	56,80	65,81
P4 Score	3	29,38	25,09	25,05	33,71

Note. *SD* = standard deviation

The findings indicate the students' PSP is strongest in understanding a problem and making a plan to solve the problem. Students are weaker in executing a plan and weakest in interpreting their findings.

4.4 Research Question 3

Which students, with respect to

4.4.1 Age,

4.4.2 Prior Mathematics or Mathematics Literacy and

4.4.3 Data Handling training or experience, or none,

display better problem-solving proficiency?

Descriptive Statistics were calculated for demographic data. It describes the relevant characteristics of the participants, i.e. the distribution of their Ages, their Mathematics background (Mathematics/Mathematics Literacy/neither at school) in Grade 12 and whether they had Data Handling (Statistics) training at school or not. The descriptive statistics for each variable will be individually discussed below.

Analysis of Variance (MANOVA and ANOVA) statistical test procedures for testing the statistical significance of the mean differences of variables and Chi²-tests were done to determine whether biographical variables of Age, Gender, Mathematics background (Grade 12) and Data Handling (Statistics) background are related to students' problem-solving proficiency (PSP). See Table 11 for MANOVA results. The table shows that none of the *p*-values are statistically significant (all $p > 0,05$), i.e. Age, Gender, Mathematics background (Grade 12) and Data Handling (Statistics) training at school have no affect on PSP.

Table 11. *MANOVA Results – showing statistical significance between PSP and the variables*

		df		
	F	Effect	Error	*p*
Age	1,060	12	309,84	0,394
Gender	1,381	4	117,00	0,245
Maths/Math Lit	0,624	8	234,00	0,758
Data Handling	0,805	4	117,00	0,525

Notes. F = F-ratio; *df* = degrees of freedom;

p = statistical significance

The univariate results are listed in Table 12.

Each one of the variables of Age, Mathematics background and Data Handling (Statistics) training at school will be discussed. Gender will be discussed in section 4.5.

Table 12. *ANOVA Results – showing statistical significance between PSP and each of the variables*

		df	*SS*	*MS*	*F*	*p*
P1 Score	Age	3; 120	41,60	13,90	0,04	0,990
	Gender	1; 120	1064,20	1064,20	2,92	0,090
	Maths/Math Lit	2; 120	698,50	349,20	0,96	0,387
	Data Handling	1; 120	805,30	805,30	2,21	0,140
P2 Score	Age	3; 120	445,50	148,50	0,28	0,842
	Gender	1; 120	349,10	349,10	0,65	0,421
	Maths/Math Lit	2; 120	692,60	346,30	0,65	0,526
	Data Handling	1; 120	1580,40	1580,40	2,95	0,088
P3 Score	Age	3; 120	872,50	290,80	0,44	0,727
	Gender	1; 120	307,80	307,80	0,46	0,498
	Maths/Math Lit	2; 120	414,00	207,00	0,31	0,733
	Data handling	1; 120	1936,60	1936,60	2,91	0,091
P4 Score	Age	3; 120	4864,69	1621,56	2,67	0,050
	Gender	1; 120	31,88	31,88	0,05	0,819
	Maths/Math Lit	2; 120	227,59	113,79	0,19	0,829
	Data Handling	1; 120	1115,33	1115,33	1,84	0,178

Notes. SS = Sum of Squares; *MS* = Mean Square; *F* = F-ratio; *p* = statistical significance

4.4.1 Problem-solving proficiency and Age.

Table 13 is a summary of the descriptive statistics of problem-solving proficiency (PSP) levels and Age of the participants.

Table 13. *Descriptive Statistics for PSP levels and Age*.

		Total	Age (years)			
			18-19	**20-21**	**22-23**	**24-31**
	n	128	14	39	45	30
P1 Score	Mean	72,53	73,81	72,22	72,96	71,67
	SD	19,12	18,16	19,43	20,42	17,99
P2 Score	Mean	74,22	79,76	72,65	75,37	71,94
	SD	23,14	21,86	25,14	23,97	20,12
P3 Score	Mean	61,72	72,02	59,83	62,04	58,89
	SD	25,80	24,59	27,16	25,10	25,61
P4 Score	Mean	29,61	42,14	28,21	33,33	20,00
	SD	25,05	23,59	21,51	28,20	22,13

Notes. n = sample size; *SD* = Standard deviation

The percentage of participants who were 18 to 19 years of age is 11%, 31% were 20 to 21 years, 35% were 22 to 23 years and 23% were 24 years and older. It can be seen from these Statistics that participants of all age groups achieved lower in P1 than in P2. Table 13 shows that as the participants got older, they were less proficient in solving the problems. The highest score was 79,76% for P2 for the ages 18-19 years. Except for age 22-23 years, PSP scores decreased from ages 18-19 years to age of 24 years and older, also from P2 to P4. Only 20% (6) of participants of 24 years and older was proficient in P4.

Figure 13 displays the performance of the different age groups on the various PSP levels graphically.

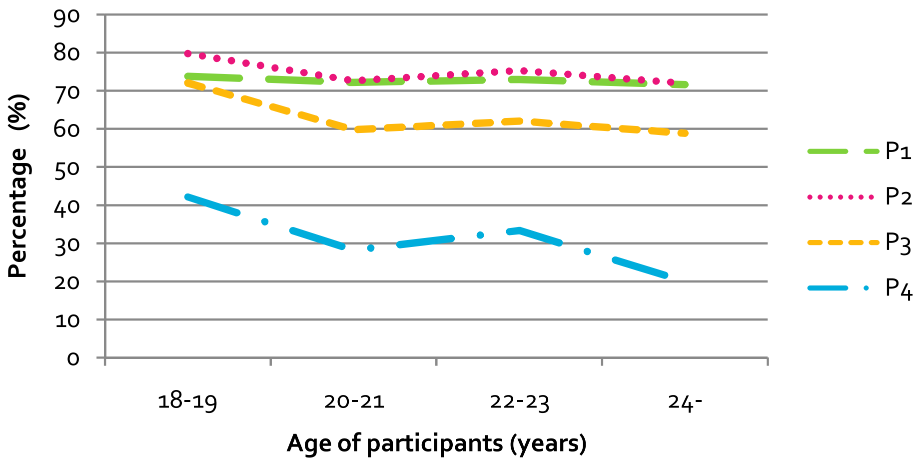


Figure 13. PSP performance and Age.

Figure 13 shows that participants were strongest in understanding a problem (P1) and making a plan (P2). It also points out that participants were less proficient in executing a plan (P3) and weakest in interpreting their findings (P4). The younger participants, i.e. age 18-19 years, achieved higher than the others in all PSP levels and have, therefore, scored the highest PSP. Participants aged 24 years and older were weakest in all PSP levels, in particular with interpreting their findings (P4).

The univariate analysis (See Table 12 on p. 84) indicates that Age, although not statistically significant, could play a role in P4 (p = 0,050). To investigate this observation, Scheffè p-values were calculated to evaluate differences between Age categories (Table 14).

Table 14. *Scheffè's p for differences between Age categories*

Age(Cat 1)	**Age(Cat 2)**	**Diff(M_1-M_2)**	**Scheffé *p***
18-19	20-21	13,94	0,350
18-19	22-23	8,81	0,713
18-19	24-31	22,14	0,056
20-21	22-23	-5,13	0,823
20-21	24-31	8,21	0,597
22-23	24-31	13,33	0,157

Notes. Cat 1 = Category 1; Cat 2 = Category 2; Diff = Difference; M_1 = Mean (Category 1); M_2 = Mean (Category 2).

None of the Scheffè p-values (Table 14) were statistically significant (all p > 0,05), i.e. there are no differences between the Age categories with respect to their role in participants' PSP. Chi²-tests were done in another attempt to determine if Age played a role in participants' PSP (See Table 15). These tests revealed no statistically significant results (all p > 0,05), i.e. no Age category played a role in participants' PSP (Table 15). Based on the results of these tests, it can be concluded that, in this study, Age did not influence problem-solving proficiency.

Table 15. *Summary of Chi²-tests (Age and PSP)*

Age cat / PSP level	**Chi²- value**	***df***	***p***
P1	5,364	6	0,498
P2	2,923	6	0,818
P3	3,199	6	0,783
P4	8,358	6	0,213

Notes. Age cat = Age category; PSP = problem-solving proficiency; *df* = degrees of freedom; *p* = statistical significance.

In summing up, it should be noted that although younger participants performed better than older participants in this assessment (See Figure 13 on p. 86), statistical tests do not indicate an association between Age and PSP. The PSP profiles for the different age groups are the same, i.e. best performance in P1 and P2 weaker performance in P3 and weakest performance in P4.

4.4.2 Problem-solving proficiency and Mathematics background.

It can be seen in Figure 14, which represents participants' Mathematics background graphically, that the majority of participants took Mathematics (Grade 12) at school.

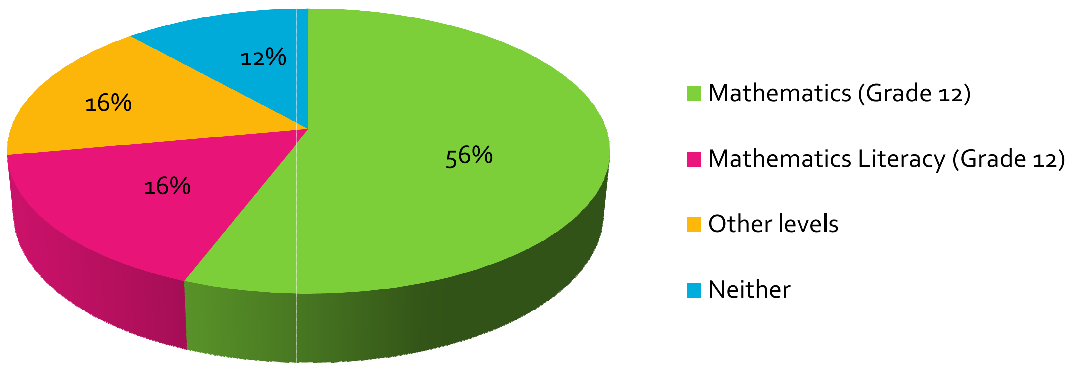


Figure 14. Mathematics Background.

A summary of the participants' Mathematics background in the year of the study (Table 16) indicates that with regards to Grade 12, 72 of the 129 participants passed Mathematics, 21 passed Mathematics Literacy, 21 passed these subjects on other levels, e.g. international students, and 15 participants took neither Mathematics nor Mathematical Literacy. This demographic information revealed that 72% of the participants took Mathematics or Mathematics Literacy at school passed Grade 12 in these subjects in South Africa. Table 16 shows that 75,5% of these participants passed Grade 12 before 2009. This is alarming information because it means that 75,5% of participants took Quantitative Techniques three years or more after the passed Grade 12 Mathematics or Mathematics Literacy. Mathematics or Mathematics Literacy must be practiced regularly, therefore, to have no exposure to either for three or more years, creates problems for students taking courses that rely on this knowledge.

Table 16. *Summary of Participants' Mathematics background (Mathematics Literacy background)*

Final Year	Grade 10	Grade 11	Grade 12	Total
2000			1	1
2001				
2002				
2003	1			1
2004	2		1	3
2005	(1)	1	3 (1)	4 (2)
2006		1	11	12
2007	1 (1)	1	29 (1)	31 (2)
2008			14 (7)	14 (7)
2009			13 (12)	13 (12)
Total	**4 (2)**	**3**	**72 (21)**	**79 (23)**

Notes. ( ) = Number of participants who passed Mathematics Literacy

The univariate analysis (See Table 12 on p. 84) reveals no statistical significant difference between problem-solving proficiency (PSP) and Mathematics background, i.e. the p – values for all PSP level are greater than 0,05. This means that there is no association between PSP and Mathematics background.

Descriptive Statistics for the PSP levels and Mathematics background are reflected in Table 17. The mean scores for participants who took Mathematics at school are the highest on all

PSP levels, followed by those who took Mathematics Literacy (except for the P1 score) than those who did neither Mathematics nor Mathematics Literacy.

It can be seen in Table 17 that the P1 to P4 scores are almost on the same level for Mathematics, Mathematics Literacy and neither. The average difference between participants' PSP scores on all levels for those who had Mathematics, those who took Mathematics Literacy and those who had neither at school is 2,99%, which is low.

Table 17. *Descriptive Statistics for PSP levels and Mathematics background*

		Total	**Mathematics**	**Mathematics Literacy**	**Neither**
	n	128	86	23	19
P1 Score	Mean	72,53	74,03	68,48	70,61
	SD	19,12	17,45	20,56	24,27
P2 Score	Mean	74,22	76,16	71,74	68,42
	SD	23,14	21,36	24,84	28,41
P3 Score	Mean	61,72	63,08	59,78	57,89
	SD	25,80	24,44	28,72	28,93
P4 Score	Mean	29,61	30,12	30,00	26,84
	SD	25,05	26,41	23,93	20,56

Notes. n = sample size; *SD* = Standard deviation.

Figure 15 shows that the PSP performance trends for participants who did Mathematics at school, those who did Mathematics Literacy and those did neither are similar. This emphasises the fact that Mathematics background has no effect on PSP.

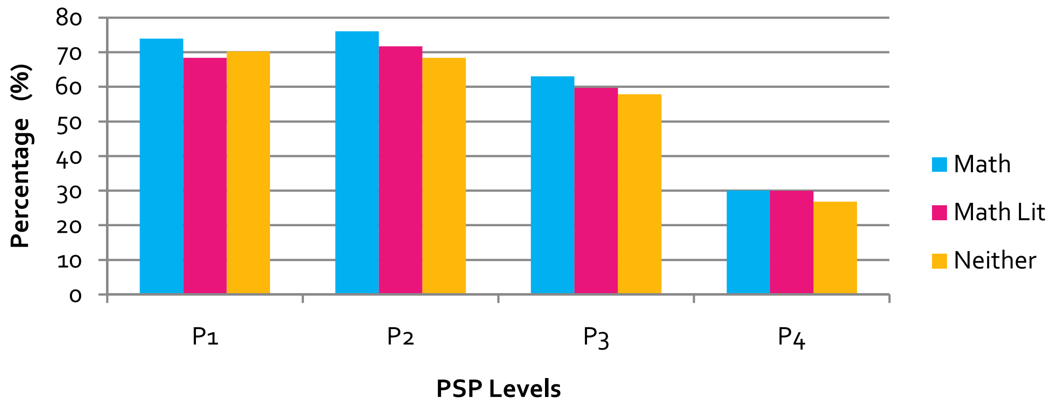


Figure 15. PSP performance and Mathematics background.

The findings of this analysis indicate that there is no association between PSP and Mathematics background. The majority of participants took Mathematics at school. The PSP profiles for participants who took Mathematics, Mathematics Literacy or neither at school are the same, i.e. best performance in P1 and P2, weaker in P3 and weakest in P4. Participants who took Mathematics Literacy performed slightly weaker than those with Mathematics and those with neither performed even weaker than those with Mathematics Literacy.

4.4.3 Problem-solving proficiency and Data Handling.

Descriptive statistics revealed that only 27% of participants received Data Handling training at school, while 73% did not (Table 18). The multivariate analysis (See Table 11 on p. 83) shows no significant association between the participants' PSP and Data Handling done at school. The univariate analysis (See Table 12 on p. 84) indicates that Data Handling taken at school, though not statistically significant (p = 0,088 for P2 and p = 0,091 for P3), could affect participants' proficiency in making a plan and executing the plan.

Table 18 reflects the descriptive Statistics for PSP levels and Data Handling.

Table 18. *Descriptive Statistics for PSP levels and Data Handling at school*

			Data Handling	
		Total	**No**	**Yes**
	n	128	94	34
P1 Score	Mean	72,53	71,01	76,72
	SD	19,12	19,69	17,01
P2 Score	Mean	74,22	71,81	80,88
	SD	23,14	23,29	21,67
P3 Score	Mean	61,72	58,78	69,85
	SD	25,80	26,25	22,94
P4 Score	Mean	29,61	27,23	36,18
	SD	25,05	25,63	22,43

Notes. n = sample size; *SD* = Standard deviation.

The statistics in Table 18 show that the problem-solving proficiency (PSP) of participants who had Data Handling training at school is on average 8,7% higher than those who did not take Data Handling at school. The biggest difference is for executing the plan (P3). Here participants who had Data Handling training at school achieved 11,07% higher than those who did not do Data Handling. Figure 16. PSP levels and Data Handling at school. represents these findings graphically. It shows similar trends for participants who had Data Handling training at school and those who did not. Participants who did not receive Data Handling training at school performed on a slightly lower level than those who took Data Handling at school.

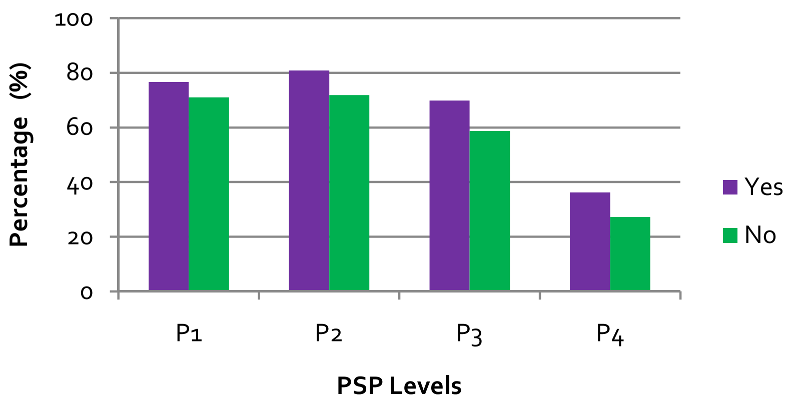


Figure 16. PSP levels and Data Handling at school.

The findings of this analysis show that only 27% of the participants did Data Handling at school. Although there is no association between PSP and Data Handling training at school, it could play a role in making a plan and executing the plan. The PSP profiles for taking Data Handling at school or not are the same, i.e. best performance in P1 and P2 weaker performance in P3 and weakest performance in P4. The results of this section of the investigation indicate that taking Data Handling at school does not influence problem-solving proficiency in Quantitative Techniques

4.5 Research Question 4.

Which Gender group tends to display better problem-solving proficiency?

The proportion of female participants was 60%, with and male participants 40%. The MANOVA (See Table 11 on p. 83) did not indicate any statistical significance (all $p > 0{,}05$), i.e. Gender does not play a role in participants' problem-solving proficiency (PSP). Table 19 summarizes the descriptive Statistics for PSP levels and Gender. It indicates that female participants achieved on average 3,96% higher PSP in P1, P2 and P3 than male participants. For P4 female achievement is 0,32% lower than male performance.

Table 19. *Descriptive Statistics for PSP levels and Gender*

			Gender	
		Total	**Male**	**Female**
	n	128	51	77
P1 Score	Mean	72,53	69,12	74,78
	SD	19,12	19,17	18,88
P2 Score	Mean	74,22	72,39	75,43
	SD	23,14	22,70	23,49
P3 Score	Mean	61,72	59,80	62,99
	SD	25,80	25,53	26,06
P4 Score	Mean	29,61	29,80	29,48
	SD	25,05	26,11	24,49

Notes. n = sample size; *SD* = Standard deviation.

The graphical display of these data in Figure 17 shows similar trends for female and male participants, although female participants performed slightly better than male participants.

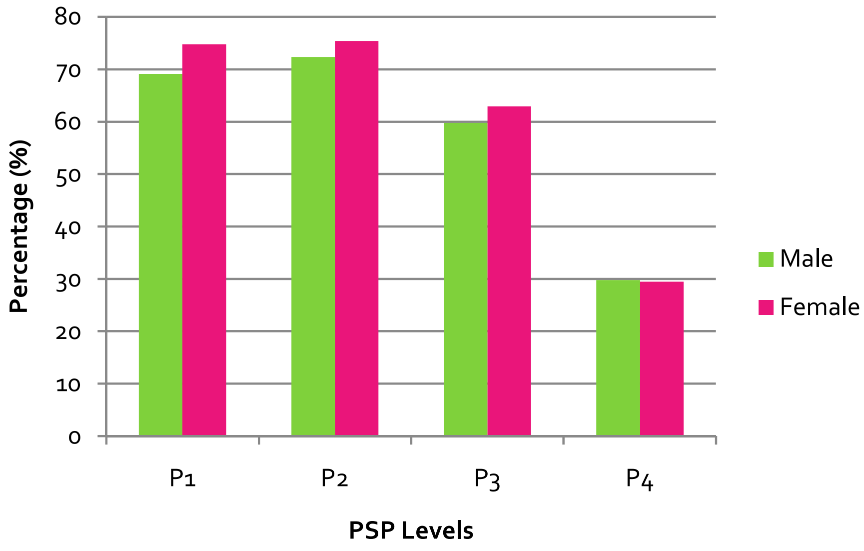


Figure 17. PSP levels and Gender.

The univariate results (See Table 12 on p. 84) reveal that, although Gender is not statistically significant, i.e. $p = 0{,}09$, for P1, Gender could influence understanding a problem (P4). Chi^2-tests were carried out to test statistically if there was any association between Gender and PSP. The results of these tests are summarised in Table 20. The results in Table 20 indicate that there is no statistical significance (all $p > 0{,}05$), i.e. there is no association between Gender and participants' PSP.

Table 20. *Summary of Chi²-tests (Gender and PSP)*

Gender / PSP level	**Chi²- value**	***df***	***p***
P1	3,433	2	0,180
P2	0,736	2	0,964
P3	0,910	2	0,634
P4	1,197	2	0,550

Notes. PSP = Problem-solving proficiency; *df* = degrees of freedom; *p* = statistical significance

To summarise, descriptive statistics indicated that female participants performed slightly better than male participants in understanding the problem, making a plan and executing the plan and the univariate analysis suggests that Gender could influence understanding a problem. However, the multivariate analysis and the Chi²-tests confirmed that there is no association between Gender and participants' PSP. The PSP profiles for the male and female participants are the same, i.e. best performance in P1 and P2 weaker performance in P3 and weakest performance in P4.

4.6 Summary of the data analysis.

The following is a summary of the analysis of this study.

Research Question 1: *What is the level of problem-solving proficiency (PSP) of Quantitative Techniques students at WSU?*

Participants' proficiency in solving Quantitative Techniques problems, based on Polya's model for problem-solving, were determined. The PSP was determined for four levels of problem-solving and the results were:

- Understanding a problem (P1 = 72,29%).
- Devising a plan (P2 = 73,77%).
- Carrying out the plan (P3 = 61,39%).
- Interpreting the findings (P4 = 29,38%).

Research Question 2: *What problem-solving weaknesses or strengths do Quantitative Techniques students at WSU display?*

This study revealed that participants were strongest in understanding a problem (P1) and making a plan to solve the problem (P2). They were weaker in carrying out the plan (P3) and weakest in interpreting their findings (P4). This pattern also showed up in the analyses carried out to answer the other research questions and can, therefore, be accepted as a PSP profile for Quantitative Techniques students.

Research Question 3: *Which students, with respect to*

3.1 Age,

3.2 prior Mathematics or Mathematics Literacy and

3.3 Data Handling training or experience, or none,

display better problem-solving proficiency?

The results of this research indicated that there is no association between PSP and Age, Mathematics background and learning of Data Handling at school. It also showed that Age might play a role in interpreting results (P4) and that knowledge of Data Handling might play a role in executing a plan (P3). A graphical display of performance of the different age groups revealed that younger participants performed better than older participants, i.e. PSP decreased over Age (See Figure 13 on p. 86). The performance of participants who took Mathematics at school is only slightly better than those who took Mathematics Literacy or neither. Only 27% of participants took Data Handling at school. All participant groups have similar PSP profiles, i.e. that participants were strongest in understanding a problem (P1) and making a plan to solve the problem (P2). They were weaker in carrying out the plan (P3) and weakest in interpreting their findings (P4).

Research Question 4: *Which Gender group tends to display better problem-solving proficiency (PSP)?*

The study revealed that there is no association between PSP and Gender. It showed that Gender might play a role in interpreting results (P4). As in the other studies carried out in this research, both Gender groups were strongest in understanding a problem (P1) and making a plan to solve the problem (P2). They were weaker in carrying out the plan (P3) and weakest in interpreting their findings (P4).

CHAPTER 5

DISCUSSION OF RESULTS

5.1 Introduction

This study sought to determine the problem-solving proficiency of Quantitative Techniques students at WSU. Attempts were made to answer the following questions:

1. What is the level of problem-solving proficiency (PSP) of Quantitative Techniques students at WSU?
2. What problem-solving weaknesses or strengths, with regards to problem-solving proficiency, do Quantitative Techniques students at WSU display?
3. Which students, with respect to
   3.1 Age,
   3.2 prior Mathematics or Mathematics Literacy and
   3.3 Data Handling training or experience, or none,
   display better problem-solving proficiency?
4. Which Gender group tends to display better problem-solving proficiency (PSP)?

In my research I found that researchers such as Dewey, Polya , Krulik and Rudnik (in Carson 2007), Carson (2007), Wu (2004) and Wu and Adams (2006) support an information processing approach as a method to unravel the cognitive and metacognitive processes situated in a problem-solving task. Such an approach can be used as a model to provide a problem-solving proficiency profile of students. In this study I used Polya's four problem-solving stages as an information processing approach to answer the research questions.

In this section my findings are discussed, based on the objectives of the study.

5.2 Problem-solving proficiency levels of participants.

Polya's model was used to quantify the crucial underlying cognitive and metacognitive proficiencies needed to execute the sequential steps in problem-solving. The Problem-solving proficiency of the participants in Quantitative Techniques problems were quantified in terms of :

i. Understand the problem.
ii. Can make a plan to solve the problem.
iii. Can execute the plan.
iv. Can interpret the results.

I believe that Polya's problem-solving model provided a useful instrument to measure problem-solving proficiency (PSP). This study revealed that participants scored an average PSP of 59,19%, based on the model derived from Polya's four stages of problem-solving. No similar research in Quantitative Techniques of post-matriculation students could be found to compare results.

The present research supports the findings of a study by Marriott, Davies and Gibson (2009) who researched the problem-solving ability of year eight and year nine pupils in Data Handling. They felt that the overall performance in problem-solving was not good. The problem-solving proficiency trend found in the current study compared well with the trend indentified in Marriott et al.'s study, i.e. in both studies participants performed high in understanding a problem and making a plan, weaker in executing the plan and weakest in interpreting their results.

The results of the current research are also supported by the findings of a study by Zakaria and Yusoff (2009) of students of Algebra at a matriculation college in Malaysia. They based their analysis of participants' problem-solving skills on Mayer's model in terms of skills required for problem translation, problem integration, solution planning and solution execution. This model is comparable with Polya's four stages of problem-solving, though Polya combined Mayer's first and second stages as 'understanding a problem'. Polya's model added a last stage of 'looking back'. In this study I refer to a problem-solving 'proficiency' rather than 'skill' to include all the skills needed for proficient problem-solving. Zakaria and Yusoff (2009) concluded that the problem-solving skills of students of Algebra were average. The current research findings can be compared to the findings of Zakaria and Yusoff (2009) because basic Mathematics skills, needed for Quantitative Techniques (Statistics), are taught in Algebra. Johnson and Kuennen (2006) asserted that '…basic mathematics skills are an important determinant of student success in elementary statistics…' (p. 10). Researchers have reported time and again a positive relationship between statistics achievement and basic Mathematics skills (Harlow, Burkholder, & Morrow, 2002; Onwuegbuzie, 2003; Nasser, 2004; Johnson & Kuennen, 2006; Galli, Chiesi, & Primi, 2010). Note that Mathematics at the

FET band, i.e. Grade 10, Grade 11 and Grade 12 level, as investigated in this study, is on a much higher level than basic Mathematics skills. The research of Zakaria and Yusoff is, therefore, used as comparison for the current research because basic mathematics forms the foundation for Quantitative Techniques.

In this research 72,73% was achieved for understanding the problem (P1), 73,77% for being able to make a plan to solve the problem (P2), 61,3% for being able to execute the plan and 29,38% for being able to interpret the results of the executed plan (P4) (See Table 5 on p. 67). These results, together with the fact that the percentage of participants who did not make an attempt to answer a question and those who gave incorrect answers increased from the first to the last PSP level, confirm that participants' PSP generally decreased towards the higher levels of problem-solving. A low percentage of participants (7%) scored over 80% on P4, i.e. 7% of the participants is at least 80% proficient in solving Quantitative Techniques problems and can be regarded as proficient in solving problems in this context.

The PSP trend determined in this study, i.e. good performance in P1 and P2, weaker performance in P3 and lowest performance in P4, is supported by the problem-solving trends found by Marriott et al. (2009) and Zakaria and Yusoff (2009). The trend in this study is on a lower level than the trend of Zakaria and Yusoff. Their students scored on average 83% on understanding a problem, 78% on making a plan and 70% on execution of the plan. Zakaria and Yusoff (2009) found that the average PSP of the Algebra students they studied was 77%, which they regarded as 'average'. The average PSP level of 59,19% determined for Quantitative Techniques students in this research is low, compared to the results of the study by Zakaria and Yusoff. Yunus et al. (2006) also found that the students in their study fared moderately in problem-solving. In light of the pass mark of 50% for this subject at WSU, there is much room to improve students' PSP.

5.3 Strengths and weaknesses of problem-solving proficiency.

I believe that this study succeeded in identifying the strengths and weaknesses of Quantitative Techniques students in the year of conducting the study. The research proved that Polya's model was a valuable instrument for this task.

The statistical analysis revealed that participants are strongest in P1 and P2. The *t*-tests (See Table 9 on p. 79) and ranking of the problem-solving proficiency (PSP) levels (See Table 10 on p. 81) show that participants performed best in P1 and P2. They achieved highest for both P1 (72,29%) and P2 (73,77%). A ranking of 3 for P4 suggest that they are weakest in P4 (29,38%). The frequency distributions of the PSP scores (See Table 6 on p. 74) indicate that although participants are strongest in P1 and P2, only 43% scored over 80% on P1 and 50% scored over 80% on P2, which is not very high. It also shows that few participants had scored below 20% on P1 (1%) and P2 (2%). On average 67% of participants scored below 80% for PSP. Performance in P1, P2 and P3 shows positive trends (See Figure 12 on p. 74), which indicates that a low number of participants achieved low PSP levels and the highest number of participants achieved high PSP levels. Ideally there should be no low PSP performance and only a high level of PSP performance. Performance in P4 has a negative trend, i.e. most participants (43%) achieved below 20% for interpreting the results and only 7% of participants who achieved above 80% for interpreting the results. This fact points out how weak participants really are in interpreting their results. Zakaria and Yusoff (2009) also found that students did not recheck their work. Their view is supported by Yusoff and Taib (2006) who showed that 'most students always skip over rechecking their answers'. Kaur (1998) revealed, with his investigation of problem-solving strategies of primary and secondary school students in Singapore, that students did not check the correctness of their solutions. It is my opinion that these studies support the finding in my research that students are weakest in interpreting their results.

Loucks-Horsely, Stiles, Mundry, Love and Hewson, (2010) pointed out that students must learn with understanding. It is my view that a student who learnt with understanding would complete the four stages successfully. Results show that 43% of participants achieved 80% and higher on P1 (understand the problem), 50% on P2 (make a plan), 33% on P3 (execute the plan) and only 7% P4 (interpret the results) (See Table 6 on p. 74). From these results it is clear that there is much room for learning to improve understanding.

It is also important for students to have the ability to monitor and regulate their own problem-solving activities (Yimer & Ellerton, 2006). It is my conviction that the low percentage (7%) of participants who achieved 80% and above on P4 (interpreting their results) can be an indication of participants' low ability to monitor and regulate their own problem-solving activities.

5.4 Problem-solving proficiency and Age, Mathematics background and Data Handling.

The Chi^2-tests and MANOVA suggest that there is no association between the problem-solving proficiency (PSP) levels and Age, Gender, Mathematics background and Data Handling training at school (or not). The trends for these variables are all similar from P1 to P4, i.e. highest on P1 and P2, lower for P3 and lowest for P4. The univariate analysis of PSP and different age groups, different Mathematics backgrounds and Data Handling training at school is discussed separately.

5.4.1 Problem-solving proficiency and Age.

Although the multivariate analysis did not indicate a significant association between Age and PSP (See Table 11 on p. 83), the univariate analysis (See Table 12 on p. 84) shows that Age is marginally significant in interpreting the results ($p = 0.05$ for P4). Literature concerning the association between problem-solving and Age is sparse, but this finding is supported by Lindberg, Hyde, Peterson, and Linn (2010) who asserted that Mathematics performance is, with other factors, a function of age. By comparing the performance of participants in different age groups it was found that problem-solving proficiency (PSP) decreased from P1 to P4 as age increased, i.e. the youngest participants were strongest and the older participants were weakest in PSP (See Figure 13 on p. 86). This trend can probably be explained by the fact that most participants did not come to university in the year after they completed their secondary education. Quantitative Techniques is a second-year subject which means that participants should ideally be taking it in the second year after leaving school. It needs to be mentioned that in this study 75,5% of participants completed Grade 12 before 2009, i.e. these participants registered for Quantitative Techniques three or more years after they left school. This means that they most likely had not been exposed to Mathematics for some years.

5.4.2 Problem-solving proficiency and Mathematics background.

The largest proportion of participants (67%) took Mathematics at school. Only 18% took Mathematical Literacy and 15% took neither (See Figure 15 on p. 92). A comparison of the problem-solving proficiency (PSP) achievement of participants with Mathematics, Mathematics Literacy and those with neither revealed that, on average, there is a small difference (3,27 %) between the PSP performance of these groups (See Table 17 on p. 91). The average difference between those who took Mathematics and those who took Mathematics Literacy is 3,35 %, between Mathematics and those who took neither Mathematics nor Mathematics Literacy 4,91 % and between Mathematics Literacy and those with neither Mathematics nor Mathematics Literacy 1,56 %. The performance on the various PSP levels of these groups has the same trend (See Figure 15 on p. 92). This information combined with the fact that the mulitivariate and univariate analysis revealed no statistical significance, indicates that Mathematics background does not influence PSP. This finding is a surprise.

However, Johnson and Kuennen (2006) found that course performance was not related to having taken Calculus or Business calculus. They also found basic Mathematics skills an important determinant of student success in elementary Statistics. Basic Mathematics skills assist students to analyse and reason quantitatively, as well as understand and interpret statistical measures. Johnson and Kuennen (2006) felt that firm basic Mathematics skills may be more beneficial than Calculus skills. On the other hand, Garfield and Ben-Zvi (2007) asserted that research evidence does not indicate that a student will succeed in Statistics if they are good at Mathematics, which supports the finding in this research. The result in the current study could perhaps be explained that by the fact that it can be assumed that the participants all have basic Mathematics skills if they took Mathematics and Mathematical Literacy in the higher grades at school. Further investigation is required to confirm this result.

According to this study it can, therefore, be said that no group between those with Mathematics, those who took Mathematics Literacy and those who took neither Mathematics nor Mathematics Literacy is stronger or weaker than the others.

5.4.3 Problem-solving proficiency and Data Handling.

Data Handling training at school introduces students to statistical terminology and notations. Most participants (73%) did not do Data Handling at school. Although there is no significant association between PSP and Data Handling (See Table 11 on p. 83) taken at school, the univariate analysis shows that having taken Data Handling is marginally significant in making a plan and executing the plan since the *p*-values are close to 0,05 (p = 0,088 for P2); p = 0,091 for P3) (See Table 12 on p. 84).

The PSP achievement of participants with Data Handling training at school (65,91%) is on average 8,7% higher than those who did not obtain Data Handling training at school

(57,21%). Participants with data handling seem to perform better than those without it. The uncovered PSP performance trend is again highest in understanding the problem (P1) and making a plan (P2), weaker in executing the plan (P3) and weakest in interpreting the results (P4) (See Table 18 on p. 93). The trend is the same for both groups, although participants who took Data Handling at school performed slightly better than those who did not take Data Handling at school.

The trend of poor performance in executing the plan (P3) and interpreting the results (P4) was also found by Marriott, Davies and Gibson (2009) in their study to develop a tool to assess the problem-solving ability in Data Handling of year eight and nine pupils. They found a poor performance in the 'Process' and 'Discuss' stages of their problem-solving approach (PSA). My view is that 'Executing the plan' in the current study corresponds with Marriott et al.'s 'Process' and 'Interpreting results' in the current study with their 'Discuss'. Marriott et al.'s results support the results in this study, although their research was done with pupils and the current study involves post-matriculation participants.

5.5 Problem-solving proficiency and Gender.

A comparison of the problem-solving proficiency (PSP) performance of female and male participants shows that females achieved higher than males in P1, P2 and P3. Female participants performed on average 2,89% higher than the male participants (See Table 19 on p. 95). The multivariate analysis was not statistically significant, i.e. there is no difference between the PSP of the Gender groups (See Table 11 on p. 83).

This finding is supported by, amongst numerous others, Lindberg, Hyde, Peterson and Linn (2010). Zakaria and Yusoff (2009), who studied problem-solving in Algebra, concluded that there is no Gender difference with respect to problem-solving. Adeleke (2007), who studied students' mathematical problem-solving performance, also supports this finding. Zhu (2007, p. 199) asserted that '…gender differences in mathematical problem-solving are not biologically determined while possibly influenced by the combined impact of many different factors that have biological, psychological and environmental origins …'.

The univariate analysis in this study indicates that Gender is marginally significant in understanding the problem (p = 0,090 for P1) (See Table 12 on p. 84). The PSP trends for both groups are similar, with female students' PSP slightly higher than male students' PSP.

Contrary to the current finding, Yunus et al. (2006) found in their study of the social problem-solving skills of post-matriculation students of Biochemistry that male students achieved significantly higher than female students. They asserted that female students have a tendency to expect problems to be unsolvable. Literature on problem-solving proficiency of students in tertiary education is sparce, therefore, this topic needs further examination to verify these results.

5.6 Summary of the discussion of the results.

The results of this study show that Polya's four-stage problem-solving model can be used successfully to measure the levels of problem-solving proficiency of students of Quantitative

Techniques. The use of Polya's model is supported by the fact that many other studies on problem-solving, e.g. Krutetskii (1976), Schoenfeld (1987), Stillman and Galbraith (1998), Mayer and Hegarty (1996), Carlson and Bloom (2005), Wu and Adams (2006), Yimer and Ellerton (2006), Zakaria and Yusoff (2009) and Weber and Carlson (2010), used models based on Polya's four-stage problem-solving model successfully. Although no research on problem-solving proficiency of students of Quantitative Techniques could be found, results of the current study are supported by findings of research on problem-solving and other subjects, e.g. Data Handling (Marriott, Davies, & Gibson, 2009), Algebra (Zakaria & Yusoff, 2009), Biochemistry (Anderson, Mitchell, & Osgood, 2007) and Mathematics (Dhlamini, 2012). This study suggests that the PSP levels of the students of Quantitative Techniques are lower than findings of other studies. The results show that students are strongest in understanding a problem and making a plan. This study found that students of Quantitative Techniques are weakest in interpreting their findings, which confirms findings by other researchers as mention above. Results neither indicate a significant association between PSP and Age, nor an association between Mathematics background and PSP. Although there is no significant association between Data Handling training at school and PSP, there is a marginal significance between Data Handling training at school and making a plan and executing the plan. The statistical analysis showed no association between PSP and Gender groups.

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary of the study

This study sought to determine the problem-solving proficiency of Quantitative Techniques students at Walter Sisulu University (WSU). Attempts were made to answer the following questions:

1. What is the level of problem-solving proficiency (PSP) of Quantitative Techniques students at WSU?

2. What problem-solving weaknesses or strengths do Quantitative Techniques students at WSU display?

3. Which students, with respect to

   3.1 Age,

   3.2 prior Mathematics or Mathematics Literacy and

   3.3 Data Handling training or experience, or none,

   display better problem-solving proficiency?

4. Which Gender group tends to display better problem-solving proficiency (PSP)?

A descriptive survey was used to meet the research objectives of this study. The participants in the study were second-year students at WSU, who were registered for the National Diploma in Marketing and took Quantitative Techniques as a compulsory subject in their second-year of study. The population of 129 students was targeted as participants in the study. Participants filled in a questionnaire to give their demographic details and information about their Mathematics background. They also wrote a pen and paper test which was scored to determine their problem-solving proficiency. The scoring was based on a model derived from Polya's four stages of problem-solving.

Descriptive Statistics were calculated to determine participants' level of PSP. One-sample *t*-tests and Cohen's *d* Statistics were calculated to determine the statistical significance of differences between problem-solving scores. Analysis of Variance (ANOVA and MANOVA) and Chi^2-tests were carried out to determine whether the biographical variables namely Age, Gender, Mathematics background and Data Handling training at school were related to students' problem-solving proficiencies. Pearson Product Moment Correlations and Chi^2 tests were done to determine whether problem-solving proficiencies were related to students' test marks. Chi^2-tests were done to determine whether participants' confidence level (PCL) was related to their actual performance. These tests were carried out to determine the validity and reliability of the results.

Results of this research suggest that the level of problem-solving proficiency of the participants is on average 59,19%, which leaves much room for improvement. It was found that participants' levels of understanding of a problem and making a plan to solve the problem are 72,29% and 73,77% respectively. Their proficiency in executing the plan was 61,30%. Proficiency of interpreting their results was a low 29,38%. Participants were strongest at understanding the problem and making a plan to solve it and weakest at interpreting the results. The multivariate statistical analysis indicated no significant association between PSP and Age, Mathematics background, Data Handling and Gender. Results of the univariate statistical analysis suggest that Age, Data Handling training at school and Gender might influence PSP. Graphical representations and descriptive statistics of the data revealed that younger participants displayed higher PSP than older participants while participants with high school Mathematics background performed highest on each PSP level. Those with Data Handling training achieved the highest PSP and female participants performed better than male participants.

The research results also indicated that there is a strong association between participants' PSP and their actual performance in the assessment test. This is consistent with findings by Karaoglan (2009), who also based his research on Polya's problem-solving stages. His correlational research indicated a significantly large correlation between students' problem-solving achievement and their achievement in Mathematics (Karaoglan, 2009).

In addition to the results mentioned above, I believe that this study is additionally a contribution to the research on problem-solving proficiency of students who take Quantitative Techniques, of which literature is sparse. It provides information about problem-solving proficiency of these post matriculation students, also with respect to their Age, Mathematics background, Data Handling training, or none, and Gender.

6.2 Conclusions

In an attempt to find ways to improve the low pass rate of Quantitative Techniques students at WSU, I turned to literature for answers. The dearth of literature on problem-solving proficiency and Quantitative Techniques encouraged me to pursue this study. I sought, therefore, to acquire information about the state of PSP of Quantitative Techniques students with a view to developing relevant interventions to improve the pass rate in this subject.

The research was based on Polya's four-stage problem-solving model which is an information processing approach. Given the time and resources available, I found this approach practical and a relatively easy way of obtaining the relevant information for this study. This view is supported by Wu and Adams (2006) who believe 'that problem-solving stages indentified by an information processing approach are likely to be of practical use in the classrooms.' (p. 96). Polya's model was used as guidance in developing an instrument to measure the level of problem-solving proficiency of the students. It was found that the average PSP of these students was 59,19%, which is rather low compared to a PSP of 77%, regarded as average by Zakaria and Yusoff (2009), for Algebra students at a pre-university college.

The study also determined a problem-solving proficiency profile for these students. They were strongest in understanding a problem and making a plan, weaker in executing the plan and weakest by a long way in interpreting the results. This trend is supported by research by Marriott, Davies and Gibson (2009) who studied pupils' problem-solving abilities in Data Handling. The result from the current study, that participants are weakest in interpreting results, agrees with the results of studies in Mathematics by other researchers (Zakaria & Yusoff, 2009; Yusoff & Taib, 2006). This instrument pointed out clearly what the problem areas are and this provides an understandable point of departure for the development of interventions. The purpose of interventions is to assist students to develop the problem-solving proficiencies which are important for problem-solving in Quantitative Techniques. Krutetskii's studies of the mathematical abilities of school children suggested that these abilities can be developed (Kang, 2012).

This study revealed that there is no association between PSP and Age, Mathematics background, Data Handling training at school or not and Gender. This means that Age, Mathematics background, Data Handling training at school or not and Gender are evidently not part of the problem with regards to problem-solving proficiency and need no further attention. The result that Mathematics background did not play a role was a surprise. It was expected that Mathematics background should play a role in a subject such as Quantitative Techniques since it can be seen as a derivative of Mathematics. Researchers such as Johnson and Kuennen (2006) underlined the importance of mathematics skills to help students analyse and reason quantitatively, as well as understand and interpret statistical measures. On the other hand, the result of the current research is supported by Garfield and Ben-Zvi (2007) who asserted that research evidence did not indicate that a student will succeed in Statistics if they are good at Mathematics. Further statistical tests revealed suggestions that Age, Data Handling training at school or not and Gender might play a role in PSP, but it needs further research.

I believe that the research objectives of this study were met successfully. An instrument was developed to assess students' problem-solving proficiency. The instrument can also display the weaknesses and strengths in the students' problem-solving proficiency, which can guide the development of interventions to improve their problem-solving proficiency. The finding that there is a strong association between participants' PSP and their actual performance in the assessment test supports the view that by introducing interventions to improve students' PSP, their achievement in Quantitative Techniques will improve, which will improve the pass rate in Quantitative Techniques. The ultimate goal is, of course, not only to have a higher pass rate, but to equip students with a range of different levels of cognitive skills through problem-solving while taking Quantitative Techniques. These skills can be carried over to the other courses they take and into their careers, as well as their everyday lives.

The instrument developed in this study to determine the level of problem-solving proficiency of students and a profile of their problem-solving proficiency can be a useful teaching and learning device for other instructors on all levels of instruction, as well as other areas of instruction that involves problem-solving.

6.3 Limitations and recommendations

6.3.1 Limitations of the study

Assessment for this research took place only once. The reason is that the aim was to assess participants' PSP on the maximum amount of Quantitative Techniques course material, i.e.

assessment had to take place at the end of the semester, before the final examination. Only one group of students was assessed in this study because this group was the only group of students taking this subject at this university. The study was done at one institution only. No other similar studies with students in tertiary education, with regards to problem-solving and Quantitative Techniques, could be found in the literature in order to make a comparison. Retesting could not take place to verify internal consistency reliability, because after this assessment participants wrote the final examination and left the institution on vacation.

Another concern is that the reading skills of some participants could have affected the results. It was partially taken care of by the fact that by the time the test was written, participants were familiar with the vocabulary used.

6.3.2 Recommendations

A need for remediation and intervention strategies to improve student's problem-solving proficiency has been identified. Although proficiency on all levels should be improved, the PSP profile highlights clearly, in this context, the problem areas. Interventions to improve students' weak proficiency in executing a plan and poor proficiency in interpreting results should be a priority. Research (e.g. De Groot, 1965; Kirschner, Sweller, & Clark, 2006; Paas & Van Gog, 2006; Sweller, Clark, & Kirschner, 2010) indicated that domain specific problem-solving skills can be taught.

The implementation of an introductory course for Quantitative Techniques should be investigated where attention should be paid to proficiency in problem-solving through the teaching of mathematical skills and an introduction to Quantitative Techniques. An introductory course could serve as a pre-requisite for registration for Quantitative Techniques. This agrees with Johnson and Kuennen (2006) who recommended that students with poor mathematics performance in a placement test should be required to complete an introductory Statistics course prior to taking other Statistics courses.

The suggestions that Age, Data Handling training at school and Gender might play a role in PSP should be investigated in further studies.

This study suggests that improved PSP could improve students' actual achievement in Quantitative Techniques and, therefore, the pass rate in this subject. This could spill over into other subjects and also improve overall performance. Manapure (2011) also mentions Setidisho's (1996) view that Mathematics is a fundamental science which is necessary for the understanding of most other fields. Students will also leave the institution with a higher level of cognitive reasoning, since it is believed that learning Mathematics leads to cognitive development (Tripathi, 2009). This is an advantage in any career. The information generated in this study points, therefore, towards a need for remediation.

6.3.2.1 Possible interventions to improve problem-solving proficiency.

The findings of this research suggest a means for intervention. Since participants' average PSP is not high, an attempt should be made to improve their PSP. Analysis indicated a strong association among the PSP levels, therefore, it can be concluded that improvement of one PSP level could affect the others. A case for an intervention is strengthened by the information that Age, Data Handling training at school and Gender could play a role in PSP. Special attention should be given to the weakest level of problem-solving proficiency, i.e. interpreting the results.

Possible interventions are:

i. Supplementary tuition.

   Currently lecture time and a full syllabus do not have room for extra tuition on problem-solving proficiency, but, seeing that these participants already have access to supplementary tuition, though limited, it could partially be used to specifically address PSP. Relevant material should be prepared.

ii. Introduction of E-learning.

   E-learning could be utilised by making a compulsory e-course available to improve PSP. This method has the advantage that students would be able to study and practise in their own time.

It should be noted that Zhang and Xin (2012) found that the most effective interventions are training in problem structure representation techniques, training in cognitive strategies and strategies involving assistive technology. They pointed out that assistive technologies were not as effective as human-delivered interventions, which is in alignment with research by Kroesbergen and Van Luit (2003).

6.3.2.2 Revision of course pre-requisites, course content and curriculum development.

Results of the study have implications for course pre-requisites, course content and curriculum development. Mathematics is currently a pre-requisite for Quantitative Techniques at WSU, though exceptions were made in the past. The finding that Mathematics background did not affect PSP was surprising, since the opposite is reported by other researchers (e.g. Harlow, Burkholder, & Morrow, 2002; Onwuegbuzi, 2003; Nasser, 2004; Galli, Chiesi, & Primi, 2010). As results of the study indicated that Mathematics background does not affect PSP, this condition could be revised, after further research, as a pre-requisite for Quantitative Techniques. The Mathematics background of Quantitative Techniques students needs further exploration, as it could point to weaknesses in the school syllabus or methods of teaching at schools.

6.3.2.3 Course content should be adjusted to make provision for problem-solving instruction.

I suggest that course content should be adjusted to make provision for problem-solving instruction. Implementation of Marriott, Davies and Gibson's (2009) statistical problem-solving approach, or like models, could be considered. Educational research views on statistical learning advocate teaching statistics through a problem-solving approach to improve statistical problem-solving skills (Garfield & Ben-Zvi, 2007). Marriott, Davies and Gibson (2009) concluded that all students benefit from skills acquired through problem-solving.

6.3.2.4 The curriculum for Marketing students at WSU should be adjusted to include an introductory module for Quantitative Techniques.

Finally, it is recommended that the curriculum for the Diploma in Marketing at WSU should be adjusted to include an introductory module for Quantitative Techniques. Such a module could intercept many of the problems experienced by teachers and students of Quantitative Techniques.

6.4 Suggestions for further research

The following are possibilities for further study:

i. Repeat the study to confirm the results.
ii. Repeat the study with more than one group to confirm the findings.
iii. The study could be extended to other institutions.
iv. Research the relationship between Mathematics background and PSP.
v. Investigate whether or not Age, Data Handling training at school or not and Gender play a role in PSP.
vi. The participants' confidence level (PCL) measured in the study could be an indication of the participants' belief systems. Callejo and Vila (2009) found a complex relationship between students' belief systems and approaches to problem-solving and highlighted the need to deal with students' belief systems. Further investigation of the relationship between the students' belief systems and their problem solving proficiency could be valuable.

vii. If participants' confidence level (PCL) could be an indication of the participants' belief systems, this matter needs further exploration. A study by Sangcap (2010) revealed 'that those mathematics-related belief systems are interconnected very strongly with the educational track and with gender' (p. 471). This view is in accord with a study by De Corte and Op't Eynde (2003).

The ultimate goal of this investigation into students' PSP is to equip the students to meet the social and economic needs of the 21st century. In this study it was found that students' problem-solving proficiency is not high. It indicates that there is a need to adopt measures to improve students' PSP. Results show that Age, Mathematics background and Data Handling training at school did not have a significant influence on the problem-solving proficiency of the students of Quantitative Techniques. It also revealed that a low percentage of students did Data Handling at school, which could point out a weakness in the school syllabus. The study found that Gender did not have a significant influence on the students' problem-solving proficiency. Results of the study point towards implications for course pre-requisites, course content and curriculum development. I believe that if students can be equipped with improved problem-solving proficiency, their overall academic performance will improve and they will leave the institution with higher levels of cognitive reasoning, which would be an advantage in any career.

The mere formulation of a problem is far more essential than its solution, which may be merely a matter of mathematical or experimental skills. To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks real advances in science.

Albert Einstein (1879 – 1955)

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APPENDICES

APPENDIX A:

Data sheet for collection of demographic information from participants.

Please fill in the information and mark the relevant blocks with **X.**

<table>
<tr><td>1.</td><td>Date of birth</td><td colspan="2">Year</td><td colspan="2">Month</td><td colspan="2">Day</td><td colspan="2"></td></tr>
<tr><td>2.</td><td>Gender</td><td colspan="2">M</td><td colspan="2">F</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>3.</td><td>Home Language</td><td colspan="2">English</td><td colspan="2">Xhosa</td><td colspan="4">Other (Specify)</td></tr>
<tr><td>4.</td><td colspan="3">Name of high school you attended.</td><td colspan="6"></td></tr>
<tr><td>5.</td><td colspan="3">Town/city where the school (in 4) is.</td><td colspan="6"></td></tr>
<tr><td>6.</td><td colspan="3">Subject taken at school.</td><td colspan="2">Mathematics</td><td colspan="2">Mathematics Literacy</td><td colspan="2">None of previous</td></tr>
<tr><td>7.</td><td colspan="4">Highest grade passed (subject in 6).</td><td>Gr 12</td><td>Gr 11</td><td>Gr 10</td><td colspan="2">Other (Specify)</td></tr>
<tr><td>8.</td><td colspan="4">In which year did you pass the grade/level indicated in 7?</td><td>2010</td><td>2009</td><td>2008</td><td colspan="2">Other (Specify)</td></tr>
<tr><td>9.</td><td>Symbol (subject in 6)</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td><td>G</td><td>H</td></tr>
<tr><td>10.</td><td colspan="5">Did you do any Statistics or Data Handling at school?</td><td colspan="2">Yes</td><td colspan="2">No</td></tr>
<tr><td>11.</td><td colspan="5">Contact number</td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

APPENDIX B:

Written test to determine problem-solving proficiency.

QAT1B14 **Total :** 53 marks

Test 2 : October 2011 **Time :** 80 min

STUDENT NUMBER: ....

SURNAME AND INITIALS: ……………………………………………………..……

COURSE ..……………………………………………………………………….

LECTURER:……………………………………………………………………….

- Fill answers in on the question paper
- Show all steps
- Use 2 decimal places where applicable

Here by I give permission that my test may be used for the research about the problem-solving proficiency of Quantitative Techniques students at WSU.

Signature : …………………………………….

Date : …………………………………

QUESTION 1: 7 marks

A large supermarket chain will increase its stock of bakery products if more than 20% of its customers are purchasers of bakery products. A random sample of 100 customers found 28% purchased bakery items.

1.1 Construct a 95% confidence interval estimate of the proportion of customers who purchases bakery products. (Hint : Use a critical value of 1,96)

(5)

1.2 Should the chain increase its bakery stocks? Give a reason for your answer.

(2)

Rate your solution of this problem.	Correct	Partially correct	Wrong

QUESTION 2 : 11 marks

A market researcher would like to know if there is a relationship between personality type and colour. A sample of 50 people is used to record personality and colour preference. Results are given in the table below :

	COLOUR		
PERSONALITY TYPE	**Blue**	**Red**	**Yellow**
Extroverted	5	20	5
Introverted	10	5	5

Test at a significance level of 5% if there is a relationship between personality type and colour preference.

(11)

Rate your solution of this problem.	Correct	Partially correct	Wrong

QUESTION 3 : 10 marks

A random sample of 29 clients at a local supermarket included 11 men. Test at a significance level of 5% the claim that less than 50% of all clients are men.
[Hint : Use a critical value of 1,701]

(10)

Rate your solution of this problem.	Correct	Partially correct	Wrong

QUESTION 4 : 11 marks

The table below contains the price (in cents/gram) and the quantity (in thousands of tons) of all exports of natural animal fibers from South Africa in 1992 and 2007.

	1992		2007	
	Price	**Quantity**	**Price**	**Quantity**
Merino	**45**	**70**	**50**	**80**
Lamb's Wool	**25**	**40**	**30**	**50**
Other Wool	**45**	**100**	**40**	**95**
Mohair	**200**	**10**	**250**	**20**

4.1 Calculate the quantity relative for Other Wool.

(2)

4.2 Interpret the index calculated in 4.1.

(3)

4.3 Construct the composite price index for the export of natural fibers for 2007 with 1992 as base year.

(4)

4.4 Name the index calculated in 4.3.

(2)

Rate your solution of this problem.	Correct	Partially correct	Wrong

QUESTION 5 : 14 marks

The manager of a liquor store designed an experiment to study the relationship between the number of alcoholic drinks consumed and blood alcohol concentration, seven individuals having the same body size were randomly assigned a certain number of alcoholic drinks. After a wait of 1 hour, their blood alcohol levels were checked. The results are as follows :

No of drinks	Blood alcohol level
0.5	0.01
1	0.02
2	0.05
3	0.09
4	0.10
5	0.14
6	0.20

5.1 What analysis must be done to describe the relationship between the variables?

(1)

5.2 Do the analysis in 5.1 and estimate the blood alcohol level for a person who had 5,5 drinks.

(4)

5.3 What analysis must be done to determine the strength of the relationship between the variables?

(1)

5.4 Do an analysis in 5.3 to describe to strength between the variables.

(2)

5.5 Interpret the findings in 5.4.

(2)

5.6 Draw a scatter diagram of the data given in the table.

(4)

Rate your solution of this problem.	Correct	Partially correct	Wrong

FORMULAS : QUANTITATIVE TECHNIQUES

Confidence Intervals :

$$\mu \quad : \quad \bar{x} \pm z_{\alpha/2} \cdot \frac{\sigma_x}{\sqrt{n}}$$

$$\mu \quad : \quad \bar{x} \pm t_{\alpha/2}^{n-1} \cdot \frac{s_x}{\sqrt{n}}$$

$$\mu_1 - \mu_2 : (\bar{x}_1 - \bar{x}_2) \pm z_{\alpha/2} \cdot \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$$

$$\mu_1 - \mu_2 : (\bar{x}_1 - \bar{x}_2) \pm t_{\alpha/2}^{n_1+n_2-2} \cdot \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

$$\pi \quad : \quad p \pm z_{\alpha/2} \cdot \sqrt{\frac{pq}{n}}$$

$$\pi \quad : \quad p \pm t_{\alpha/2} \cdot \sqrt{\frac{pq}{n}}$$

$$\pi_1 - \pi_2 : (p_1 - p_2) \pm z_{\alpha/2} \cdot \sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}}$$

$$\pi_1 - \pi_2 : (p_1 - p_2) \pm t_{\alpha/2} \cdot \sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}}$$

Hypothesis Tests :

$$\mu \quad : \quad Z_{calc} = \frac{\bar{x} - \mu_x}{\frac{\sigma_x}{\sqrt{n}}}$$

$$t_{calc} = \frac{\bar{x} - \mu_x}{\frac{s_x}{\sqrt{n}}}$$

$$\mu_1 - \mu_2 : Z_{calc} = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

$$t_{calc} = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{S^2}{n_1} + \frac{S^2}{n_2}}}$$

where

$$S^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

$$\pi \quad : \quad Z_{calc} = \frac{p - \pi}{\sqrt{\frac{\pi(1-\pi)}{n}}}$$

$$t_{calc} = \frac{p - \pi}{\sqrt{\frac{\pi(1-\pi)}{n}}}$$

$$\pi_1 - \pi_2 : Z_{calc} = \frac{(p_1 - p_2) - (\pi_1 - \pi_2)}{\sqrt{\hat{\pi}(1-\hat{\pi})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where $\hat{\pi} = \dfrac{x_1 + x_2}{n_1 + n_2}$

OR $$Z_{calc} = \frac{(p_1 - p_2) - (\pi_1 - \pi_2)}{\sqrt{\frac{\pi_1(1-\pi_1)}{n_1} + \frac{\pi_2(1-\pi_2)}{n_2}}}$$

$$\chi^2_{calc} = \Sigma \frac{(f_0 - f_e)^2}{f_e}$$

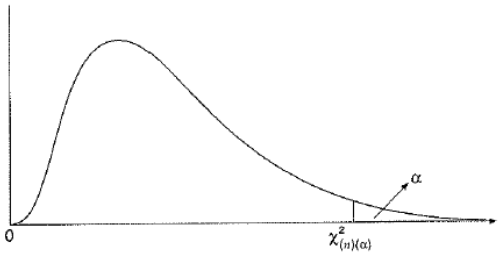
Index Numbers :

$$P_L = \frac{\Sigma(p_c \times q_b)}{\Sigma(p_b \times q_b)} \times 100 \qquad P_P = \frac{\Sigma(p_c \times q_c)}{\Sigma(p_b \times q_c)} \times 100$$

$$Q_L = \frac{\Sigma(p_b \times q_c)}{\Sigma(p_b \times q_b)} \times 100 \qquad Q_P = \frac{\Sigma(p_c \times q_c)}{\Sigma(p_c \times q_b)} \times 100$$

TABLE 3
The Chi-square distribution (χ^2)

This table gives the value of $\chi^2_{(n)(\alpha)}$ where n is the degrees of freedom i.e. $\boxed{} = P\left(\chi^2 > \chi^2_{(n)(\alpha)}\right)$



α / df	0.100	0.050	0.025	0.01	0.005	0.0025
1	2.707	3.843	5.026	6.637	7.881	9.142
2	4.605	5.991	7.378	9.210	10.597	11.983
3	6.251	7.815	9.348	11.345	12.838	14.321
4	7.779	9.488	11.143	13.277	14.860	16.424
5	9.236	11.071	12.833	15.086	16.750	18.386
6	10.645	12.592	14.449	16.812	18.548	20.249
7	12.017	14.067	16.013	18.475	20.278	22.040
8	13.362	15.507	17.535	20.090	21.955	23.774
9	14.684	16.919	19.023	21.666	23.589	25.462
10	15.987	18.307	20.483	23.209	25.188	27.112
11	17.275	19.675	21.920	24.725	26.757	28.729
12	18.549	21.026	23.337	26.217	28.300	30.318
13	19.812	22.362	24.736	27.688	29.819	31.883
14	21.064	23.685	26.119	29.141	31.319	33.426
15	22.307	24.996	27.488	30.578	32.801	34.950
16	23.542	26.296	28.845	32.000	34.267	36.456
17	24.769	27.587	30.191	33.409	35.718	37.946
18	25.989	28.869	31.526	34.805	37.156	39.422
19	27.204	30.144	32.852	36.191	38.582	40.885
20	28.412	31.410	34.170	37.566	39.997	42.336
21	29.615	32.671	35.479	38.932	41.401	43.775
22	30.813	33.924	36.781	40.289	42.796	45.204
23	32.007	35.172	38.076	41.638	44.181	46.623
24	33.196	36.415	39.364	42.980	45.558	48.034
25	34.382	37.652	40.646	44.314	46.928	49.435
26	35.563	38.885	41.923	45.642	48.290	50.829
27	36.741	40.113	43.195	46.963	49.645	52.215
28	37.916	41.337	44.461	48.278	50.993	53.594
29	39.087	42.557	45.722	49.588	52.336	54.967
30	40.256	43.773	46.979	50.892	53.672	56.332
31	44.422	44.985	48.232	52.191	55.003	57.692
32	42.585	46.194	49.480	53.486	56.328	59.046
33	43.745	47.400	50.725	54.776	57.648	60.395
34	44.903	48.602	51.966	56.061	58.964	61.738
35	46.059	49.802	53.203	57.342	60.275	63.076
36	47.212	50.998	54.437	58.619	61.581	64.410
37	48.363	52.192	55.668	59.892	62.883	65.739
38	49.513	53.384	56.896	61.162	64.181	67.063
39	50.660	54.572	58.120	62.428	65.476	68.383
40	51.805	55.758	59.342	63.691	66.766	69.699
45	57.505	61.656	65.410	69.957	73.166	76.233
50	63.167	67.505	71.420	76.154	79.490	82.664
60	74.399	79.087	83.305	88.386	91.957	95.357
70	85.529	90.537	95.031	100.432	104.222	107.812
80	96.581	101.885	106.636	112.336	116.329	120.107
90	107.568	113.151	118.144	124.125	128.307	132.262
100	118.501	124.348	129.570	135.815	140.178	144.300
110	129.388	135.487	140.925	147.423	151.958	156.238
120	146.571	152.222	157.389	163.678	168.122	172.351
140	168.618	174.659	180.174	186.875	191.604	196.099
160	190.522	196.926	202.766	209.852	214.845	219.588
180	212.310	219.056	225.200	232.647	237.890	242.866

APPENDIX C:

Scoring templates for the written test.

Estimation : Question 1.			Memorandum
Polya stage	**Mark**	**Show proficiency to:**	
1: Understand the problem.	2	Understand the problem fully, i.e. all of the following correct: • procedure • parameter(s).	• Correct procedure: Calculate a Confidence Interval • n = 100; p = 0,28; α = 0,05 ⇒ $Z_{crit} = 1{,}96$
	1	Understand partially, i.e. any of the following: • uses correct procedure, but incorrect parameter. • uses correct parameter, but incorrect procedure.	
	0	Do not understand the problem, all of the following incorrect: • procedure • parameter(s).	
	9	No attempt.	
2: Devise a plan.	2	Correct plan: • Use correct formula to calculate the interval estimate.	$p \pm Z.\sqrt{\frac{pq}{n}}$
	1	Partially devise a plan : • Copies the formula incorrectly.	
	0	Cannot devise a plan : • Selects incorrect formula.	
	9	No attempt	
3: Execute the plan.	2	Correct execution of plan : • Calculates correct answer.	$0{,}28 \pm 1{,}96.\sqrt{\frac{0{,}28(0{,}72)}{100}}$ $\therefore 19{,}2\% < \pi < 36{,}8\%$
	1	Executes plan partially correct : • Calculation error.	

	0	Cannot execute the plan : • No answer.	
	9	No attempt.	
4: Look back.	2	Interpret question correctly by giving the correct answer, i.e. each of the following correct: • decision • reason • significance level.	• Yes, the chain should increase its bakery stocks, • because the interval estimate includes 20%, • calculated with a confidence level of 95%
	1	Partially correct interpretation, i.e. at least one of the following correct: • decision • reason • significance level.	
	0	Incorrect interpretation, i.e. all of the following omitted or incorrect: • decision • reason • significance level.	
	9	No attempt.	

Test for independence of association. (X^2-test) : Question 2.			**Memorandum**
Polya stage	**Mark**	**Show proficiency to:**	
1: Understand the problem	2	Understand the problem fully, i.e. all of the following correct: • procedure • hypothesis.	• Selects X^2- test. • H_0: Personality type and preferred colour are independent. H_a: Personality type and preferred colour are associated.
	1	Understand partially, i.e. at least one of the following correct: • procedure • hypothesis.	

	0	Does not understand the problem, i.e. all of the following omitted or incorrect: • procedure • hypothesis	
	9	No attempt.	
2: Devise a plan.	2	Correct plan, i.e. all of the following correct: • critical $\boldsymbol{X^2}$-value • decision rule • formula to calculate X^2_{calc}- statistic.	• $X^2_{crit} = X^2_{3;0,05} = 5{,}991$ • Reject if $X^2_{calc} > 5{,}991$ • $X^2_{calc} = \sum \frac{(f_0 - f_e)^2}{f_e}$
	1	Partially devise a plan, i.e. . at least one of the following correct: • critical $\boldsymbol{X^2}$-value • decision rule. • formula to calculate X^2_{calc}- statistic.	
	0	Cannot devise a plan, i.e. all of the following omitted or incorrect: • critical $\boldsymbol{X^2}$-value • decision rule and • formula to calculate X^2_{calc}- statistic.	
	9	No attempt	
3: Execute the plan.	2	Correct execution of plan, i.e. all correct of: • calculation of sample statistic (use table) • answer	• Use table to calculate $X^2_{calc} = \sum \frac{(f_0 - f_e)^2}{f_e}$ • $X^2_{calc} = 9{,}029$
	1	Executes plan partially correct, i.e. at least one of the following correct: • calculation of sample statistic (use table) • answer.	
	0	Cannot execute the plan, i.e. all of the following incorrect: • calculation of sample statistic (use table) • answer	
	9	No attempt.	

4: Look back.	2	Interpret result correctly, i.e. all correct of: • decision • reason • significance level • conclusion.	• Reject H_0 • $X^2_{calc} = 9{,}029 > X^2_{crit} = 5{,}991$ • Tested at a 5% significance level • There is an association between personality type and preferred colour.
	1	Partially correct interpretation, i.e. incorrect or omitted information in interpretation, at least one of the following is correct: • decision • reason • significance level • conclusion	
	0	Incorrect interpretation, i.e. incorrect and omitted information in interpretation, all of the following incorrect: • decision • reason • significance level • conclusion	
	9	No attempt.	

Hypothesis testing : Question 3.			**Memorandum**
Polya stage	**Mark**	**Show proficiency to:**	
1: Understand the problem	2	Understand the problem fully, i.e. each of the following: • Selects correct procedure • States hypothesis correctly.	• Procedure: Hypothesis test • $H_0: \pi = 0{,}5$ $H_0: \pi < 0{,}5$

	1	Understand partially, i.e. at least one of the following correct: • Selects correct procedure, but incorrect parameter • Selects correct parameter, but incorrect hypothesis.	
	0	Does not understand the problem, i.e. any of the following: • Selects wrong procedure • Identifies parameter and hypothesis incorrectly.	
	9	No attempt.	
2: Devise a plan.	2	Correct plan, i.e. each of the following correct: • Sample size and parameter • Critical value • Decision rule • Formula to calculate sample statistic.	• $n = 29; p = \frac{11}{29} = 0,379$ • $\alpha = 0,05 \implies t_{crit} = t_{28;0,05} = -1,701$ • Reject if $t_{calc} < t_{crit} = -1,701$ • $t_{calc} = \frac{p - \pi}{\sqrt{\frac{\pi(1-\pi)}{n}}}$
	1	Partially devised a plan, i.e. at least one of the following correct: • Sample size and parameter • critical value • decision rule • formula to calculate sample statistic.	
	0	Cannot devise a plan, i.e. all of the following incorrect: • Sample size and parameter • critical value • decision rule • formula to calculate sample statistic.	
	9	No attempt	
3: Execute the plan.	2	Correct execution of plan, i.e. all of the following correct: • substitution • answer.	• $t_{calc} = \frac{0,379 - 0,5}{\sqrt{\frac{0,5(1-0,5)}{29}}}$ • $t_{calc} = -1,303$

	1	Executed plan partially correct, i.e. at least one of the following correct: • Correct substitution, but incorrect answer • Correct substitution, but no answer • Incorrect substitution, but correct answer for the incorrect substitution.	
	0	Cannot execute the plan: • incorrect substitution and incorrect answer for incorrect substitution.	
	9	No attempt.	
4: Look back.	2	Interpret result correctly, i.e. each of the following correct: • decision • reason • significance level • conclusion	• Do not reject H_0 • $t_{calc} = -1{,}303 > t_{crit} = -1{,}701$ • Tested at a significance level of 5% • The proportion of men in equal to 50%.
	1	Partially correct interpretation, i.e. incorrect or omitted information in interpretation, at least one of the following correct: • decision • reason • significance level • conclusion	
	0	Incorrect interpretation, i.e. incorrect and omitted information in interpretation, all of the following incorrect: • decision • reason • significance level • conclusion	
	9	No attempt.	

Index Numbers : Question 4.1 & 4.2			Memorandum
Polya stage	**Mark**	**Show proficiency to:**	
1: Understand the problem	2	Understand the problem fully, i.e. all the following correct: • procedure • calculate a quantity index	• Procedure: Calculate an index number • Use quantities
	1	Understand partially, i.e. at least one of the following correct: • procedure • calculate a quantity index	
	0	Does not understand the problem, i.e. all of the following incorrect: • procedure • calculate a quantity index	
	9	No attempt.	
2: Devise a plan.	2	Correct plan, i.e. all the following correct: • base period quantity • current period quantity • formula to calculate the index number.	• $q_c = 95$ • $q_b = 100$ • $Quantity\ relative = \frac{q_c}{q_b} \times 100\%$
	1	Partially devised a plan, i.e. at least one of the following correct: • base period quantity • current period quantity • formula to calculate the index number.	
	0	Cannot devise a plan: • base period quantity • current period quantity • formula to calculate the index number.	
	9	No attempt	
3: Execute the plan.	2	Correct execution of plan, i.e. all the following correct: • substitution • answer.	• $Quantity\ relative = \frac{95}{100} \times 100\%$ • $Quantity\ relative = 95$

	1	Executed plan partially correct, i.e. at least one of the following correct: • Correct substitution but incorrect answer • Error with substitution, but correct answer for the incorrect substitution.	
	0	Cannot execute the plan: • Incorrect substitution and incorrect calculation	
	9	No attempt.	
4: Look back.	2	Interpret index number correctly, i.e. all the following correct: • period • change in activity (increase/decrease) • random variable.	• 1992 to 2007 • decrease of 5% • Quantities of wool exported
	1	Partially correct interpretation, i.e. at least one of the following correct: • period • change in activity (increase/decrease) • random variable.	
	0	Incorrect interpretation, i.e. all of the following incorrect: • period • change in activity (increase/decrease) • random variable.	
	9	No attempt.	

Index Numbers : Question 4.3			**Memorandum**
Polya stage	**Mark**	**Show proficiency to:**	
1: Understand the problem	2	Understand the problem fully, i.e. all the following correct: • procedure • calculate a price index	• Procedure: Calculate an composite index number • Laspeyres Price index

	1	Understand partially, i.e. at least one of the following correct: • procedure • calculate a price index	
	0	Does not understand the problem, i.e. all of the following incorrect: • procedure • calculate a price index	
	9	No attempt.	
2: Devise a plan.	2	Correct plan, i.e. correct: • formula to calculate the index number.	• $P_L = \frac{\Sigma p_c.q_b}{\Sigma p_b.q_b} \times 100\%$
	1	Partially devised a plan, i.e. any of: • error in copying the formula • use Paasch formula.	
	0	Cannot devise a plan, i.e. any of: • calculate a quantity index • calculate a price relative • calculate a quantity relative.	
	9	No attempt	
3: Execute the plan.	2	Correct execution of plan, i.e. all the following correct: • substitution • answer.	• $P_L = \frac{11200}{10650} \times 100\%$ • $P_L = 105{,}164$
	1	Executed plan partially correct, i.e. at least one of the following correct: • Correct substitution but incorrect answer • Error with substitution, but correct answer for the incorrect substitution.	
	0	Cannot execute the plan: • Incorrect substitution and incorrect calculation	
	9	No attempt.	
4: Look back.	8	No interpretation was required.	

Regression analysis : Question 5.2.			Memorandum
Polya stage	**Mark**	**Show proficiency to:**	
1: Understand the problem	2	Understand the problem fully, i.e. all correct of: • procedure • variables.	• Procedure: Regression analysis • Independent variable (x): Number of drinks Dependent variable (y): Blood alcohol level
	1	Understand partially, i.e. at least one of the following correct: • Selects correct procedure, but identified variables incorrectly. • identifies variables correctly, but procedure incorrectly.	
	0	Does not understand the problem, i.e. both of: • Selects wrong procedure • Identifies variables incorrectly.	
	9	No attempt.	
2: Devise a plan.	2	Correct plan, i.e. all correct of: • Regression equation • Substitute x	• $\hat{y} = a + bx$ • $x = 5{,}5$
	1	Partially devised a plan, i.e. at least one of the following correct: • Regression equation • Substitute x	
	0	Cannot devise a plan, i.e. all of the following incorrect: • Regression equation • Substitute x	
	9	No attempt	
3: Execute the plan.	2	Correct execution of plan, i.e. all correct of: • values for *a* and *b* • regression equation • substitution • answer.	• $a = -0{,}013$; $b = 0{,}033$ • $\hat{y} = -0{,}013 + 0{,}033x$ • $\hat{y} = -0{,}013 + 0{,}033(5{,}5)$ • $\hat{y} = 0{,}169$

	1	Executed plan partially correct, i.e. at least one of the following correct: • Calculates correct values for a and b, but writes down incorrect regression equation. • Calculates the incorrect values for *a* and/or *b*, but writes down the correct regression equation for incorrect values for *a* and/or *b*. • Calculates the correct values for *a* and/or *b* and did not write down the regression equation. • Correct regression equation, but no substitution. • Correct regression equation and substitution, but incorrect answer.	
	0	Cannot execute the plan, i.e. all of the following incorrect: • values for *a* and *b* • regression equation • substitution • answer	
	9	No attempt.	
4: Look back.	2	Interpret regression question correctly, i.e. answer the question in words containing the following correctly: • both random variables • units of measurement.	• The blood alcohol level after • 5,5 drinks is 0,169
	1	Interpret regression question partially correct, i.e. answer the question in words containing at least one of the following correct: • both random variables • units of measurement.	
	0	Incorrect interpretation, i.e. answer the question in words containing all of the following incorrectly: • both random variables • units of measurement.	