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A Study of Student Teachers' Performance and Psychological Characteristics in Learning Introductory Statistics

by

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Abstract

This study seeks to explore the learning of introductory statistics by student teachers, the work being carried out in Malaysia. Statistics is often thought of as a subject that is difficult to learn and understand, especially when the course is mandatory. Undoubtedly, many would acknowledge that statistics is an important subject to learn in these days and age where its uses and applications are ubiquitous. However, due to its poor image and, possibly, the way it is being taught, a majority of these students may be likely to approach the learning of statistics with caution or even with trepidation.

The research study for this thesis was carried out in three stages. In the first stage, factors that might affect the learning of introductory statistics for student teachers were investigated. The factors were attitudes related to learning statistics, and the effects of the limitation of the student teachers' psychological characteristics (namely, perceptual fields or the degree of field dependency and working memory space). In addition to these factors, student teachers' performances in a test to identify misconceptions in basic descriptive statistics concepts and probability and also in their final statistics examination were scrutinised.

The results from the first stage indicated that student teachers generally had positive attitudes toward learning statistics but *not* toward the introductory statistics course which was described as dull or uninspiring and too mathematical. The student teachers appeared not to cope with the task of taking down the lecture notes and simultaneously trying to understand the statistical concepts to be learned. Student teachers' performance in the statistics examination revealed a significant correlation with their working memory although not with their degree of field dependency. From the test, misconceptions about certain concepts in basic descriptive statistics and probability were identified. These correlations may reflect the nature of the test materials as much as the nature of statistics.

Based on the findings from the first stage, interactive statistics learning materials employing the cooperative learning method were developed in the second stage and given to an experimental group of student teachers from five teacher training colleges. Another group of student teachers (called the comparison group) from the same colleges were taught the same materials but through the traditional lecture method. A post-questionnaire and a test based on the materials learned were given to both groups after the completion of the second stage study. The degree of field dependency for the student teachers in both groups was also measured.

Results from the post-questionnaire revealed that the experimental group overwhelmingly favoured the learning units that were based on the interactive and cooperative learning while the comparison group regarded the lecture method as being dull and uninspiring. It also appeared that learning statistics based on the cooperative learning method was more favoured by the male student teachers, the Non-Mathematics Education group and the field dependent student teachers. Perhaps, not surprisingly, the experimental group performed better than the comparison group in the test based on the learning materials.

In the third stage, opinions were sought from the student teachers in their final semester of study, concerning their readiness to teach statistics in school. They also sat a multiple-choice test about basic concepts in descriptive statistics and probability. In addition, the working memory capacity and the degree of field dependency of the student teachers were also measured. The findings revealed that a majority of the student teachers did not have confidence in teaching statistics. This probably stemmed from the difficulty in understanding certain statistical concepts and perhaps the statistics courses that they had attended did not provide them with a good training. The findings from the test also revealed that misconceptions in some statistical concepts still persisted and that the student teachers appeared to have forgotten some, if not all, statistical subject matter that they had previously learned in the statistics lectures. Generally, these findings indicated the weaknesses of the traditional format of teaching introductory statistics course through the lecture method.

It should be pointed out that all these conclusions derived from this study must be treated tentatively due to the limitations of this research. The study has highlighted several problems and a few suggestions for further work have been made.

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CHAPTER ONE

INTRODUCTION TO THE RESEARCH STUDY

1.1 The Purpose of the Research Study

According to many statistics educators (e.g: Reid & Petocz, 2002; Moore, 2001; Roiter & Petocz, 1996; Yilmaz, 1996; Garfield & Ahlgren, 1988; Crocker, 1981), statistics is a subject with the image of being notoriously difficult both to teach and to understand especially to students in fields like education or psychology. These students possibly have their first encounter with statistical concepts when they enrol in an introductory statistics course. The introductory statistics course is often taught and regarded as a mathematics subject. Therefore, more often than not, the emphasis is on learning the computational techniques and formulas to be used in data manipulation. Thus, this could be one of the many reasons why students fail to enjoy introductory statistics course and find it difficult to learn. This is compounded with the many abstract concepts in statistics as well as the statistical notations and terminologies that are often confusing and ambiguous. The delivery of the course's content, which is usually through the lecture method, is another cause for concern. Thus, the way the course is being presented and taught is likely to alienate students since they are not being able to interact with the learning materials sufficiently. Students with poor mathematical background or lack of commitment to the usefulness of statistics for themselves may well be in disadvantageous positions. Overall, these students might also have negative views about learning statistics.

With the above factors in mind, it was thought that an investigation into student teachers' learning of introductory statistics at Sultan Idris Education University (SIEU) and some of the teacher training colleges in Malaysia would be the most appropriate purpose for this research study. This investigation covered areas like student teachers' attitudes toward learning statistics, cognitive factors affecting their learning of statistics, misconceptions in understanding basic statistical concepts and alternative approaches to teaching statistics to them. The research study was carried out in three stages over a period of two years with different groups of student teachers in each stage. The stages are briefly described as follows:

- In the first stage (exploratory study), a survey of the student teachers' attitudes toward learning statistics was carried out using a self-administered questionnaire. This was followed with three tests: the Hidden Figures Test (to measure the degree of field dependency), the Digit Span Backwards Test (to measure the size of the working memory capacity) and a structural communication grid test on basic descriptive statistics and probability concepts (to identify misconceptions). Final examination scores were also obtained and then compared with the scores from the tests described above in order to determine whether significant relationships existed between the scores. The main research question here was whether the cognitive factors (field dependency and working memory) had effects on the student teachers' performances in the statistics examination and tests. The scores obtained from the tests and statistics examination as well as the responses given to the questionnaire were also analysed and compared according to gender (male or female), programmes of study (Mathematics Education or Non-Mathematics Education) and categories of field dependency.
- In light of the findings in the first stage, the second stage was devoted to making comparisons between two approaches to teaching statistics to the student teachers (divided into two groups): one group was exposed to learning units developed by the researcher incorporating a cooperative learning method while the other group followed the traditional lecture method. A pre-questionnaire, a post-questionnaire, a structural communication grid test and also the Hidden Figures Test (to measure the degree of field dependency) were given to both groups. In addition, final examination scores were also obtained. Results obtained from the tests were analysed and compared so as to determine whether significant differences occurred between the groups and also between the genders, programmes of study and categories of field dependency within the groups.
- In the third stage, the focus of the research study was on the final-year student teachers enrolled in the methodology course in mathematics education. The aim of this stage of the research study was to survey the student teachers' knowledge and misconceptions about descriptive statistics and probability concepts by using a multiple-choice test as well as their readiness to teach

statistics in school through a self-administered questionnaire. Their degree of field dependency and the size of the working memory capacity were also measured and then set out against the scores obtained from the test in order to determine whether significant correlations occurred between them.

Since this study was about student teachers who were mostly from SIEU learning introductory statistics, it would be appropriate to describe in brief about SIEU and also the introductory statistics course being taught there in the following two sections.

1.2 Sultan Idris Education University

Sultan Idris Education University (SIEU), formerly known as Sultan Idris Teacher Training Institute is Malaysia's premier and oldest teacher training college and was established in the year 1922. It was given university status by the Malaysian Government in 1997. It is the only university in Malaysia, exclusively catering for teacher education, that offers courses ranging from the Bachelor of Education (B.Ed) degree programmes to doctorate programmes. However, other public universities do have their own Faculty of Education which also offer B.Ed degree programmes in various fields, the post graduate diploma in education course and other post graduate programmes. In addition, there are 25 teacher training colleges which are run by the Ministry of Education that provide courses such as the Malaysian Teaching Diploma course (for primary education) and also the post graduate certificate of education course. There is also a special programme for experienced non-graduate teachers (those with only certificates or diplomas), jointly organised by the Ministry of Education and SIEU, to enable them to become graduate teachers. In this programme, the former teachers are to enrol in the first year of the Bachelor of Education degree course at five of the teacher training colleges and then proceed to continue the course at SIEU from the second year onwards. This programme is in line with one of the ministry's stated aims to have all secondary school teachers and 50% of the primary school teachers to be graduate teachers by the year 2010 (EPRD, 2000). Currently, only 70% of the secondary school teachers are graduates while the number of graduate teachers in primary schools is negligible.

1.2.1 The Faculty of Science and Technology

There are six faculties at SIEU and the Faculty of Science and Technology is one of the biggest. It comprises three departments: Mathematics, Science and. Information Technology. To gain admission into the faculty, applicants must have either a diploma or a matriculation certificate or a Malaysian High School Certificate (equivalent to GCE 'A' level or Scottish Higher Grade) with good grades (at least a Grade C) in the subjects they are applying to. A general requirement is that all applicants must have at least a Grade C in the Malaysian Certificate of Examination's (MCE) mathematics paper (equivalent to a GCSE or Scottish Standard Grade mathematics). Non-graduate teachers can also apply for admission provided that they have at least five years of teaching experience and good grades (at least Grade C) in MCE's mathematics and other subjects related to the course they are applying for.

1.2.2 The Bachelor of Education (B.Ed) Programmes

The duration of the B.Ed degree programmes is for four years that covers eight semesters. A typical B.Ed degree programme in the Faculty of Science and Technology, as well as for the rest of the university includes five components which are listed below:

a) Basic university courses such as Malay Language, English Language, Islamic & Asian Civilisations and Multimedia.
b) Basic courses in education such as curriculum & pedagogical studies, educational sociology, educational psychology and studies in testing, measurement & evaluation.
c) Teaching practicum to be held in schools during the final semester.
d) Minor option
e) Major option

The major option component consists of 17 courses and it is based on the programme of study (Mathematics Education, Science Education or Information Technology Education) into which the student teachers are enrolled. The minor option component has 8 courses and this can be selected from within the faculty or from other faculties. As an example, student teachers from the Mathematics Education programme will take up courses in applied mathematics, pure mathematics, statistics and mathematics education (methodology) as their major option component. They can then choose some courses from the Science Education programme or the Information Technology Education programme (within the faculty) or choose courses such as from the Accounting Education programme (from the Faculty of Business & Economic Studies – outside the faculty) to be their minor option component. In order to be conferred the B.Ed degree, a student teacher has to pass all the courses and obtain a minimum CGPA (cumulative grade point average) score of 2.0.

1.3 The Introductory Statistics Course

The introductory statistics course is one of the courses listed under the major option component for all programmes of study in the Faculty of Science and Technology and is therefore compulsory for all student teachers enrolled in the faculty. It is also listed as one of the eight courses offered by the Department of Mathematics to student teachers from other programmes of study outside the faculty who wish to pursue the Mathematics Education programme as their minor option. As such, it is not surprising if the total enrolment into the introductory statistics course during every academic session is high (about 200 to 300 student teachers in each semester).

The introductory statistics course, which is offered by the Faculty's Mathematics Department, adopts the traditional syllabus structure of descriptive statistics, probability and inferential statistics to be covered in one semester (a general discussion of a typical introductory statistics course at tertiary level can be found in section 3.4.3). The complete syllabus for the course is given in Appendix A. The course seems to emphasise the mathematical techniques and data manipulation with a great amount of formulation and rarely, if ever, with the interpretation of statistics. A pre-requisite for this course is that student teachers should have already enrolled in the algebra and calculus courses in the preceding semester which suggests that the mathematical level of the course is quite high.

The only teaching strategy employed in the teaching of the introductory course is by the lecture method where the lecturer would give the facts and figures as well as some examples in the form of problems with step-by-step solutions which are read out from the transparencies on the overhead projector or written down on the white board. The student teachers' only role is to spend the whole time in the lecture hall copying down the notes religiously from the white board. Obviously, no discussion takes place during the lecture between the lecturer and the students or between the students themselves. The only time the student teachers have the opportunity to raise questions or discuss about the subject matter with the lecturer or the tutor is during the tutorial that is held once a week. However, the tutorial session is often dominated with the tutor giving more examples to the statistical problems that involve a lot of calculations or helping the student teachers with their weekly assignment (problem sheet) rather than discussions about the concepts learned during the lecture.

The assessment for the introductory statistics course is based on a set of quizzes, a mid-semester test and a final examination. Most of the items asked in these assessments are computational-based which merely require the student teachers to reproduce the algorithmic techniques learned during the lectures and apply to a different set of numbers or data. It is regrettable that no project work is given to the student teachers so as to enable them to practise the statistical knowledge that they are supposed to have acquired. Many reasons might be found to this lamentable situation such as the constraint of time and the rush to cover the whole syllabus in one semester or difficulty in assessing the project work.

1.4 The Structure of the Thesis

Before discussing the outcomes of this study, a review of relevant aspects of the literature is offered. This looks at the nature and teaching of statistics against a background of how learning occurs. In the light of this, the methodology, results and discussions of the findings from the study are outlined.

In more detail,

- Chapter Two discusses the roles of statistics in society especially in the field of education. Developments of statistics education in primary and secondary schools are reviewed so as to determine its place in the curriculum.
- Chapter Three reviews the problems in teaching and learning statistics from the primary right up to the tertiary levels. Areas of interest include the attitudes of teachers and students toward teaching and learning statistics respectively, suitable statistics curriculum for students at each level, the way

statistics is being taught and the difficulties that students encounter in learning statistics.

- Chapter Four seeks to explore what learning for understanding really means. To help explain how students can learn with understanding, some learning models are reviewed.
- Chapter Five looks at the field dependence/independence cognitive style of learning since it is widely acknowledged that unique differences among individuals do exist and these might have impact on their learning. Discussions about two teaching strategies are also presented.
- Chapter Six describes in detail the first stage of the research study.
- Chapter Seven describes in detail the second stage of the research study.
- Chapter Eight describes the third stage of the research study.
- Chapter Nine summarises the findings as well as drawing conclusions and implications from all stages of the research study.

The whole study not only seeks to offer an overview of statistics education but also to explore aspects of the problems in learning statistics in a meaningful way. Although the study is set in a context of student teachers learning statistics in a Malaysian university and five teacher training colleges, with the sample involved, it is likely that the outcomes can be generalised to the learning of statistics in many other contexts.

CHAPTER TWO

STATISTICS EDUCATION AND SOCIETY

2.1 Introduction

The use and applications of statistics are ubiquitous. If we pick up a daily newspaper, we would find charts, graphs and words such as 'unlikely', 'chances', 'average', 'trends', 'correlations', 'estimates' and 'margin of errors'. They are all in the domain of statistics. The quantitative information is important to all of us in making decisions or simply to keep us well informed. Similarly, when we tune in to a radio station, turn on the television or surf the internet we would probably be inundated with a lot of data and claims from the advertisers and pollsters. Some might be true and some might be just blatant exaggeration.

As consumers and citizens of the world, we have to be careful when we are bombarded or confronted with abundant statistical information. The statistics may appear credible but it may be misused which leads to statistical doublespeak – the inflated, involved, and often deliberately ambiguous use of numbers (Haack, 1979). Statistics can also be thought as an appealing secret language which is used to sensationalise or to oversimplify (Huff, 1993). When Benjamin Disraeli, the 19th century British Prime Minister, coined the infamous phrase 'Lies, Damned Lies and Statistics', he highlighted a popular conception of statistics as selectively manipulating and distorting real world data (Rogerson, 1986). Some people make cynical remarks about statistics, like the famous psychologist Carl Jung who claimed that *'you can prove anything with statistics'* which is of course not really true (Klass, 2002), or Esar's sarcastic description of statistics as the science of producing unreliable facts from reliable figures (Gaither & Cavazal-Gaither, 1996).

According to Best (2001), there are good statistics and bad statistics. We need good statistics to help us to summarise and clarify the nature of our complex society such as when we talk about social problems. Best described bad statistics as numerical information based on nothing more than pure guesses or sourced from dubious data. He argued that bad statistics are potentially important too. For examples, they can be used to stir up public outrage or fear, they can confuse the understanding of our world and they can lead our leaders to make poor policy choices.

Statistics pervades many fields in our life such as in education, arts and science, economics, health, politics and engineering. In fact, statistics is sometimes thought as a 'users' discipline or a servant discipline (Wild and Pfannkuch, 1998). Because of its importance, society including parents, teachers, students and adults in general need to be educated in statistics. As Florence Nightingale once said:

> "*To understand God's thoughts, we must study statistics for these are the measures of His thoughts...*" (Howard, 1998).

Kopf (1977) explains that what Nightingale meant is that the universe was evolving in accordance with a divine plan and it was up to the people to understand this plan by using statistics to guide actions in line with it. A layman might not necessarily agree with Nightingale's view but it shows how relevant statistics is to explain social and natural phenomena and events that occur throughout the history of mankind.

As such, every one of use must have the skills to understand and use numbers especially since we live in a knowledge-based society and economy. In other words, we have to be statistically literate. In this context, Podehl (2002) defines statistical literacy as the ability to

- *understand and interpret statistical data;*
- *critically evaluates statistical information and data related arguments;*
- *use the information in context of daily life; and*
- *discuss and communicate one's reactions*

Thus, when we look at data, we must look at it intelligently. Moore (2001) suggests that we should ask questions such as '*what is the source of the data*?', '*do the data makes sense* ?' and '*is the information complete* ?'. Therefore, it is important for all of us, especially students at every level, to be exposed to statistics teaching or instruction. As pointed out by Nisbett *et al.* (1987), much research has provided evidence that instruction in statistics is one of the factors that help us to reason effectively about data and chance in everyday life.

In this chapter, several matters pertaining to statistics education will be discussed such as what statistics is and its history, the place of statistics in schools and in post secondary education and the future of statistics education.

2.2 A Brief History of Statistics and Probability

The notion of statistics was originally the collection of information about and for the 'state' and the word itself derives from the Latin words *status* (meaning state) and *statista* (meaning statesman) (Folks, 1981; Arsham, 2003). Folks mentioned many examples such as the gathering of descriptive information on 158 states for Alexander the Great in ancient Greece, censuses conducted for the purposes of levying taxes in conquered territories by Augustus, the ancient Roman emperor and William the Conqueror who ordered a survey of England in 1085.

Although the methods of statistics were in use much earlier, the term statistics only appeared in print in the middle of the eighteenth century in a paper written by a German philosopher, Gottfried Achenwall in which he referred to statistics as '*inquiries respecting the population, the political circumstances, the productions of a country and other matters of state*' (Haack, 1979; Zidek, 1987). However, Kennedy (1983) pointed out that the first statistician on record was thought to be John Graunt, an Englishman who collected, organised and analysed data on mortality and birth rates which was then published as the book '*Natural and Political Observations on the Bills of Mortality*' in the mid-1600s.

Probability meanwhile seems to have emerged in the early seventeenth century. It originated from the study of games of chance and gambling. According to Stigler (1986), several mathematicians including Pascal, Fermat, Bernoulli, Leibniz and Huygens investigated the ways permutations and combinations could be used to solve gaming problems and to quantify uncertain outcomes of games of chance including gambling. This led to the formulation of classical probability theory. The theory involved estimating a probability of an event by taking a ratio between the number of mutually exclusive ways that an event could occur and the total of all equally likely mutually exclusive outcomes. Bernoulli was also credited with the relative frequency probability theory which involved repeated experiments of random events and computing the probability as the proportion of times an event occurred. Bernoulli's contribution to this theory could be found in his best known work: *Ars Conjectandi* (Johnson & Kotz, 1998; Green, 1982). Another theory which yields a probability based on certain evidence or personal judgement and experience is the subjective probability theory (Green, 1981). For example, an actuary might assign subjective probability to the length of life expectancy for a person who has a terminal illness.

Due to the breakthroughs in probability theories, mathematical foundations in statistics improved significantly which led to the emergence of inferential statistics later on (Haack, 1979). By the early twentieth century, much more sophisticated statistical theory had been developed and was being applied in many areas of investigation. The two most famous statisticians of this epoch were Karl Pearson and Ronald Fisher who contributed substantially to modern statistical ideas and procedures (Folks, 1981). With the advancement of computer technology, statistics continued to drive forward and make rapid progress throughout the twentieth century.

2.3 What is Statistics?

If we were to ask ordinary people what statistics is about, probably we would obtain many answers. To most of them, statistics means numbers – numerical facts, figures or information. Others often associated statistics with counting and calculations which they find boring, tedious and difficult (Blejec, 1993). In a study on the attitudes towards statistics of students who are entering tertiary education in Australia, Philips (1990) reported that many students viewed statistics as mere number crunching exercises or making sense of data by drawing tables and graphs.

A survey of introductory statistics textbooks gives the definition of statistics as a discipline dealing with all aspects of the collection, processing, presentation and interpretation of data (Freund & Perles, 1999; Clarke & Cooke, 1992; Moore, 2001). Aliaga and Gunderson (1998) define statistics as an iterative process of learning about the world around us and the process comprised of four steps as shown in the diagram below (Figure 2.1). They argue that it is iterative because decision made may be that to update the theory and gather more data or the results do not give convincing answers and this may suggest new theories. The various components or steps (beginning with step (1)) in the process are connected and can be likened to cyclical stages.

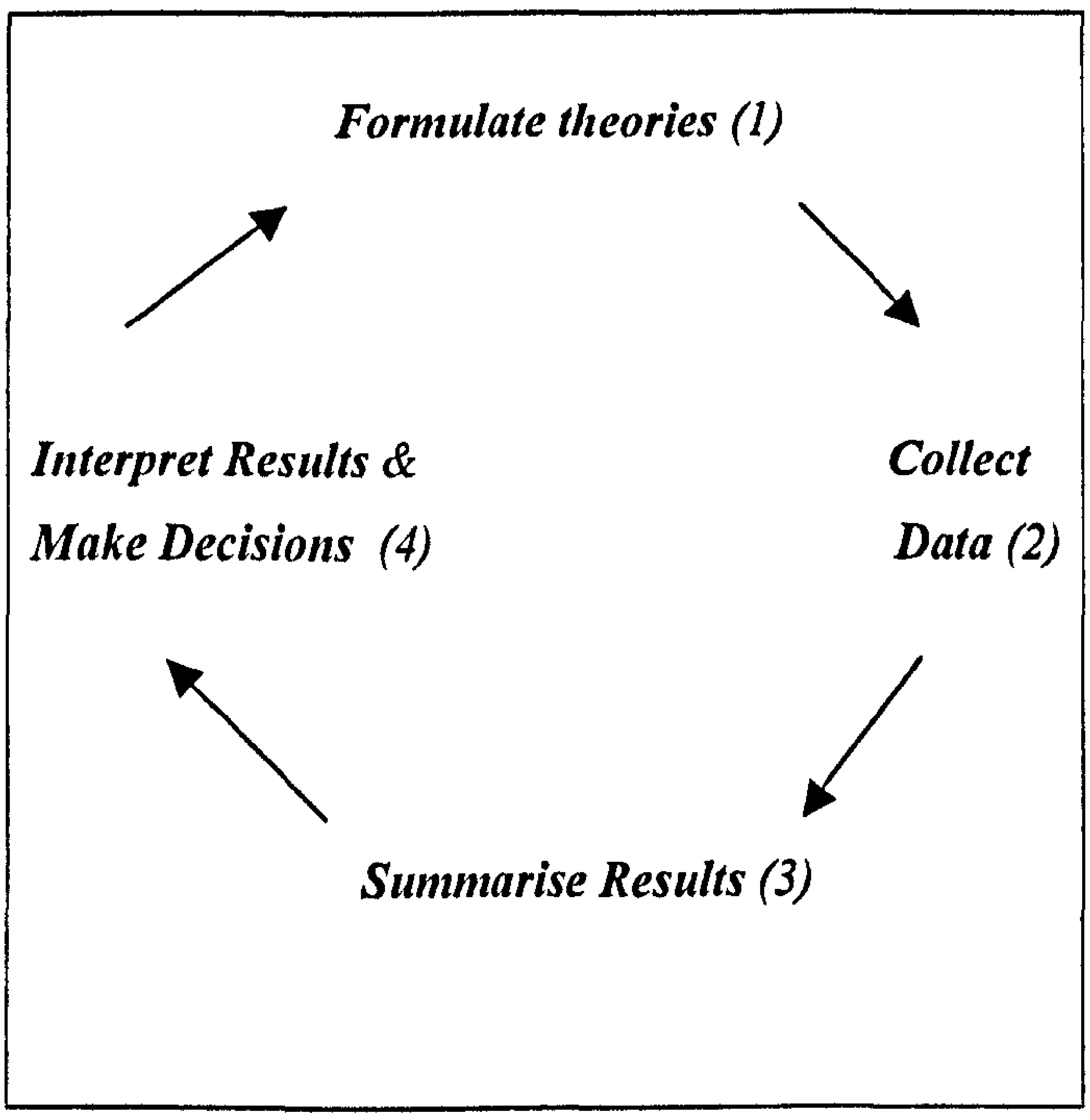


Figure 2.1 : Statistics as an iterative process of learning
Source : (Aliaga & Gunderson, 1998)

According to the Oxford Dictionary of English Etymology (Onions, 1983), statistics is more concerned with exploring, summarising and making inferences about the state of complex systems: for example, the state of a nation (official statistics), the state of people's health (medical and health statistics) and the state of the environment (environmental statistics) and so on. As such, its scope is enormous and provides useful insights into as many 'states' as our imagination allows.

Some definitions view statistics as a branch of mathematics. Without doubt, statistics had its foundations in mathematics and was considered as probabilistic inference based on mathematics (Nicholls, 1999). Moreover, Moore (1992) argues that statistics did not originate within mathematics. He stresses that statistics is a separate discipline in its own right, with its own concepts and types of reasoning and with characteristic modes of thinking that are more fundamental than either specific methods or mathematical theory.

Gal and Garfield (1997) outline five key differences between mathematics and statistics as follows:

1. *In statistics, the context motivates procedures and is the source of meaning and basis for interpretation of results of such activities.*
2. *The indeterminacy, 'messiness' or context-boundedness of statistics is markedly different from the more precise, finite nature characterising traditional learning in mathematics.*
3. *Mathematical concepts and procedures are used as part of the attempt to manage or solve statistical problems, and some technical facility with them may be expected in certain courses and educational levels. However, the need for accurate application of computations or execution of procedures is rapidly being replaced by the need for selective, thoughtful and accurate use of technological devices and increasingly sophisticated software programmes.*
4. *The fundamental nature of many statistical problems is that they do not have a single mathematical solution. Rather, realistic statistical problems usually start with a question and culminate with the presentation of an opinion that may have different degrees of reasonableness.*
5. *A primary aim of statistical education is to enable students to be able to render reasoned descriptions, judgements, inferences and opinions about data or argue about the interpretation of data, using various mathematical tools only to the degree needed. Judgements and inferences expected of students very often cannot be characterised as 'right' or 'wrong'. Instead, they have to be evaluated in terms of quality of reasoning, adequacy of methods employed and nature of data and evidence used.*

Moore (1992) also points out the difference between what a mathematician and a statistician might do regarding to numbers. The former would study numbers as abstract concepts without a context while the latter would study numbers only in the context of what these numbers might represent in this world.

Another definition of statistics includes the study of probability. Collins English Dictionary (Butterfield, 2003) in one of two definitions mentioned statistics as the classification and interpretation of quantitative data in accordance to probability theory and the application of methods such as hypothesis testing. Continental Europeans normally use the word *stochastic* for this broader definition (Garfield &

Ahlgren, 1988). Throughout this thesis the term *statistics* will be used to include statistics and probability. The inclusion of probability in the definition is probably justified because we live in a world which is full of uncertainty. Much of the present and definitely all of the future are uncertain. According to Lindley (1991), since statistics is the study of uncertainty, probability is the only sensible measure of it. It is only natural to quantify the uncertainty so that this abstract idea could be seen as something tangible to ordinary people before making any decision in any particular situation. The connection between *uncertainty* and *making decisions* is also highlighted by the Cockcroft Committee (1982) with the following statement:

> *'....statistics is not just a set of techniques, it is an attitude of mind approaching data. In particular, it acknowledges the fact of uncertainty and variability in data and data collection. It enables people to make decisions in the face of this uncertainty'.*

Biehler (1990) points out that implicit or explicit answers to the question '*what is statistics?*' have been highly variable in history. These answers, he claims, are very important in curriculum design and research as well as in teacher education. For example, Gnanadesikan and Kettenring (1988) characterise statistics as data science with close synergetic relations to mathematics and computing science. Biehler (1990) argues that this is in fact a very modern definition which brings the changed nature of statistics. He elaborates that this definition puts data at the centre of statistics and computing science on an equal standing with mathematics as a closely related discipline.

As *statistics* is such a politically contentious word (Bibby, 1987), it would not be surprising if the meaning of statistics might change in the future in tandem with progress made in other fields such as in computer technology, economy, politics and social development.

2.4 The Place of Statistics Education Within the Curriculum

According to Burnett (1982), the question 'why teach statistics' must be a crucial one in any attempt to introduce or extend the teaching of statistics. From his point of view, the justification must be based on one clear principle: statistics is a practical discipline for understanding the uncertain world that we live in and for solving the real problems in society from A to Z ! He further stresses that statistics must be central and essential to the education and training of the school pupils, the university students and the professionals. Burnett's opinion is also in concord with Pereira-Mendoza and Swift (1981) who present a rationale for teaching statistics based on utility, future study and aesthetics. Around the same time, the Schools Council Project on Statistical Education (1980) in England and Wales, lists five practical reasons on why statistics should be taught to all:

- *Statistics is an integral part of our culture.*
- *Statistical thinking is an essential part of numeracy.*
- *Exposure to real data can aid personal development and decision making.*
- *Statistical ideas are widely used at work after school.*
- *Early exposure can give sound intuition which can later be formalized.*

With this in mind, has statistics cemented its place within the educational curriculum? In the following sections, development of statistics in school curriculum will be discussed especially in the United Kingdom and Malaysia.

The history of the teaching of statistics began in the late seventeenth century in German universities (Ottaviani, 1989) which later spread to the rest of Europe and America in the eighteenth and nineteenth centuries. Throughout that period, statistics was only taught at university level although some basic measures of averages were taught for secondary schools (Jacobsen, 1989). However, there were reports of probability being taught in Hungarian schools as early as 1849 and of statistics entering school curriculum via geography in 1868 (Bibby, 1986). In Japan, statistics was included in the post-war curricula for education in all school levels (Midzuno *et al.*, 1991). In England and Wales, the first steps taken to include statistics in the school curriculum only came about in 1961 with the introduction of the General Certificate of Education (GCE) ordinary and advanced levels syllabuses (Holmes, 2003). Similarly, in Scotland, some statistical content was incorporated within the mathematics curriculum at Ordinary Grade level (for students aged 14-16) and for the mathematically able students enrolled in the Certificate of Sixth Years Studies (CSYS) courses which were introduced in the 1960s. Meanwhile in America, the American Statistical Association and National Council of Teachers of Mathematics has promoted statistics education extensively since 1967 (Burrill, 1991). Other countries like Italy and Argentina only incorporated statistics into their school curriculum as recently as in 1979 and 1994 respectively (Fabbris, 1987; de Carrera, 2002). In most of the countries mentioned earlier, statistics is a part of the general mathematics curriculum and not as an independent stream of instruction.

2.4.1. The Development of Statistics Education in the Primary Schools.

During the 1960s in England, there was a growth of practical data collection, representation and intuitive inference in primary schools in a drive towards introducing 'modern' mathematics curriculum by the country's Nüffield Foundation (Holmes, 2003). Holmes mentions that pupils were asked to collect data for themselves, representing them graphically and drawing elementary inferences from the data. Basic ideas in probability were also introduced (Nuffield Mathematics Project, 1969). However, Lionel-Mendoza (1987) points out that the major emphasis was on descriptive statistics involving graphing and tabulating data and calculating the mean.

Currently, statistics (referred to as data handling) is well entrenched in the primary mathematics curriculum in England (Holmes, 2003). According to England's Qualifications and Curriculum Authority (QCA) (1999), pupils in the primary schools are taught to:

- *solve problem involving data*
- *interpret tables, lists and charts used in everyday life, construct and interpret frequency tables including table for grouped discrete data.*
- *represent and interpret data using graphs and diagrams, including pictograms, bar charts and line graphs, using ICT where appropriate.*
- *know that mode is a measure of average and that range is a measure of spread, and to use both ideas to describe data set.*
- *recognise the difference between discrete and continuous data.*
- *draw conclusions from statistics and graphs and recognise when information is prescribed in a misleading way, explore doubt and uncertainty and develop an understanding of probability through classroom situations, discuss events using a vocabulary that includes equally likely, fair, unfair and certain.*

In Scotland, statistics was barely taught in the primary schools prior to the 1990s (Mahmud, 1997). Statistics is only given a proper place in the current mathematics curriculum in Scotland with the introduction of the National Guidelines, 'Mathematics 5-14', where it is referred to as 'Information Handling', in the early 1990's (McColl, 1999). According to the National Guidelines, 'Mathematics 5-14', the information handling strand as an attainment outcome, is concerned with the knowledge and understanding required to handle and make sense of information which includes collecting, organising, displaying and interpreting information (The Scottish Office Education Department, 1991).

In Malaysian primary schools, statistics began to be taught in the early 1970's with the introduction of the 'Modern Mathematics Programme' (Yeoh *et al.*, 1977). Prior to that, the traditional mathematics lessons concentrated mainly on the basic computational skills. The statistical lessons centred around presenting data in the form of pictographs and bar charts and doing various calculations to find percentages and averages.

Beginning in the early 1980s, the new primary school mathematics curriculum with the emphasis on problem solving was introduced. Statistics is one of the four main areas in the mathematics curriculum. According to the Malaysian's Curriculum Development Centre (CDC) (2003), the main aim of the primary mathematics curriculum is to enable the child to acquire mastery in the basic skills and that these skills are to be applied constantly to the child's real life experiences. Some of the skills involving statistics are the abilities to handle data and to present information in the form of graphs and charts. However, the ideas of probability are not introduced at this level.

2.4.2 The Development of Statistics Education in the Secondary Schools

Before the advent of modern mathematics, the only statistical technique in the standard secondary mathematics course was 'averages' which were treated from a very mathematical point of view (Holmes, 2003). Moreover, in the 1960s, many groups such as School Mathematics Project (SMP) were active in developing a modern mathematics syllabus which included probability and statistics. The contents on probability and statistics included tables, tally charts, bar charts, the mean, median, mode, range, use of statistics in newspapers, trends in time series of data, pictorial misrepresentations of data, experimental and theoretical probabilities and combinations of events by using tree diagrams. Holmes points out one weakness of the syllabus: too much emphasis on theory but weak on practical statistics.

According to QCA (1999), the programme of study for data handling (statistics) in the current national curriculum in mathematics for English secondary schools (key stages 3 and 4), emphasises the statistical process described in the cycle as in Figure 2.2 which is quite similar to Aliaga and Gunderson's cyclic stages in Figure 1.

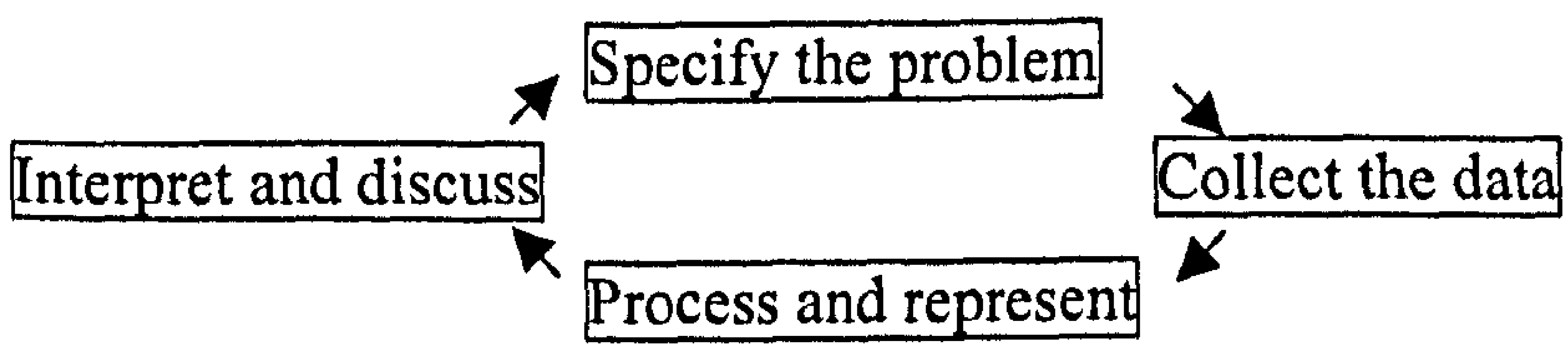


Figure 2.2 : The statistical process described by the QCA

Holmes (2003) highlights the statement in the key stage 3's programme of study (Year 11-14) that stresses pupils should be taught knowledge, skills and understanding through practical work in which they draw inferences from data and consider how statistics are used in real life to make informed decisions. He also points out that pupils in key stage 4 for the foundation are to be taught the major ideas of statistics such as identification of appropriate populations, obtaining a representative sample to draw inferences about populations, different measuring scales, probability as a measure of uncertainty and the usage of inference in making decisions. To Holmes, all this can be considered as a reasonable summary of the major ideas in statistics and statistical thinking that are appropriate for pupils of this age (11-16).

Holmes (2003) points out that statistics does not only appear in mathematics in the English national curriculum but as a matter of fact across the curriculum. In his earlier paper (2001), he gave details of the amount of statistics and statistical thinking that is required in subjects such as geography, history and science. Nevertheless, he argues that there are discrepancies between the levels of statistical competence that is required in different subjects due to the fact that these syllabuses were all developed independently. As such, the difficulties of the concepts being used were not always appreciated and the order in which the statistical ideas were introduced was often not appropriate. However, Hawkins (1991) points out that what is appropriate to the teaching of statistics as a discipline in its own right is not necessarily appropriate to statistical teaching within other subjects. So, the main concern now, according to Holmes (2003), is to how pupils could gain an integrated view of statistics. He and Rouncefield (1991) lament the fact that statistics coordinators in schools still do not exist despite being envisaged by the Cockcroft Committee (1982).

In Scotland's National Guidelines, 'Mathematics 5-14', statistical topics are only included up to Secondary 2. However, the topics are confined mainly to areas like displaying data, conducting simple sample surveys and calculating the averages. There is no mention, whatsoever, about probability. Then, statistics just drops out of the mathematics curriculum receiving no further mention in the Standard Grade syllabus (Secondary 4). As pointed out by McColl (1999), *'...Pupils can leave school without hearing the word* ***probability****...and knowing little more about statistics than how to construct a bar chart and a histogram and how to calculate a mean'.* Nevertheless, some changes are made to the Standard Grade's mathematics syllabus in 1999 so as to make some statistical topics like probability, correlation and straight-line models compulsory to students in Secondary 3 and 4 (McColl, 1999).

The inclusion of statistics and probability in the Malaysian secondary mathematics curriculum in the early 1970's was also due to the 'Modern Mathematics Programme' (Yeoh *et al.*, 1977). As was the case with the modern mathematics curriculum in England, the contents of statistics and probability were theoretical with a lot of calculations and number crunching! Topics covered were collection of data, their arrangement and presentation in tables, graphs and charts, the idea of frequency distributions and histograms, measures of location and variation, the concepts in probability such as sample space, event and randomness, calculation of probabilities for simple and combined events and the use of tree diagrams. In the mid 1980s, the Integrated Secondary School Curriculum (KBSM) was implemented. The old modern mathematics curriculum was replaced with the new mathematics curriculum in KBSM which is still in used now. The contents of the statistics and probability topics are still the same as were in the old curriculum but the emphasis is now on problem solving and practical activities with the aid of calculators, technological software, electronic spreadsheet, graphical charts and others (CDC, 2002).

2.4.3 Statistics in Post Secondary Education

Statistics is again included in the mathematics curriculum in the post secondary and pre-university education in Malaysia and in most countries. For example, in Malaysia the statistics component is included in the Mathematics S syllabus for candidates sitting for the Malaysian Higher School Certificate examination (Malaysian Examination Council, 1999). Moreover, not all students at this level are exposed to the learning of statistics since the mathematics curriculum is not compulsory. At this level, the statistics taught tends to be theoretical and mathematical with a lot of calculus used while practical and project works are not included (Ghani, 1999).

In England, statistics modules at advanced (A) and advanced subsidiary (AS) levels are all part of a mathematics qualification (Holmes, 2003). Holmes points out that most of these modules do include some practical and project work while the mathematics side of the subject is played down. In Scotland, statistics does appear in Paper 1 (statistics) and Paper 111 (mathematics general paper with some statistical content) at Higher Grade level but only for the benefit of the most able mathematics students (McColl, 1999).

Due to the importance of statistics, colleges and universities around the world require students to study the infamous, stand alone and generic 'introductory statistics' course (Gal & Garfield, 1997) in a variety of fields including science, economics, psychology, engineering and education. The main aim of these introductory courses should be to enable students to have basic grasp of statistics especially the handling of data: how to collect, process using appropriate techniques and interpret the results obtained in their respective areas of their study (Pieraccini,1991; Schuyten,1991). For example, in the University of Glasgow, the Department of Statistics provides introductory statistics courses (Statistics 1B and Statistics 1C) for students majoring in non-mathematics courses such as psychology and social science. One of the interesting features of these courses is the level of mathematics used which is kept to a minimum. The main emphasis of these courses is on the application of statistics like how to pose answerable questions, design an appropriate experiment or survey, apply sensible statistical procedures to the data obtained and, finally, interpret and report the answers to the questions posed on the basis of the analysis (Department of Statistics, University of Glasgow, 2003).

2.5 Summary

More than a century ago, H.G. Wells made a prediction: '*Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write*' (Campbell, 1974). It is probably happening now with advances in Information Technology (IT) that has resulted in a much more data-based and knowledge-based society. Undoubtedly, a rudimentary knowledge of statistics is essential for all of us to understand and to make sense the numerical and graphical information that is in abundance around us. It must also be pointed out that statistics is not merely about numbers or number crunching exercises but encompasses the aspects of collecting, presenting and interpreting data. It can also be viewed as an iterative process of learning about the world around us especially in helping us to make decisions which could determine our future.

In education, elementary statistics and probability are now considered fundamental for all students from primary level onwards. However, much needs to be done to enhance the standing of statistics in the curriculum. For instance, statistics should be a subject in its own right and not as part of the mathematics curriculum. The emphasis in school statistics should also change from 'knowing' statistics to 'doing statistics' (investigating), 'thinking statistically' (reasoning), interpreting media reports (communicating) and so on (Begg, 1998). To realise these changes, many problems in the teaching and learning of statistics have to be overcome. An overview of these problems is presented in the next chapter.

CHAPTER THREE

TEACHING AND LEARNING STATISTICS: THE PROBLEMS

3.1 Introduction

Although currently, a statistics component can be found in most schools' mathematics curriculum, it is not really straightforward for its teaching and learning according to many research reports (such as from the papers presented in the International Conference on Teaching Statistics (ICOTS) from the year 1982 to 2002). As with other subjects, problems in teaching and learning statistics do exist whether at the primary, secondary or tertiary levels. The claims that statistics is neither easy to learn nor to teach are not far from the truth and research has shown how students are not learning what teachers want them to, or how they (the students) could not apply what they do learn to unfamiliar problems (Romberg and Carpenter, 1986; Garfield and Ahlgren, 1988; Scholz, 1991; Shaughnessy, 1992). In this chapter, many issues relating to the teaching and learning of statistics will be outlined and discussed as posed by the following questions:

- *Are the teachers teaching statistics qualified to teach it?*
- *What are the attitudes of the teachers toward teaching statistics?*
- *What areas of statistics should be taught to primary school pupils, secondary school students or student teachers in teacher training colleges?*
- *How to teach statistics?*
- *What are the attitudes of students toward learning statistics?*
- *What are the difficulties students encounter in understanding statistical concepts?*
- *Which areas in statistics cause the difficulties?*

These issues and questions will be discussed under two broad headings: a) problems in teaching statistics (sections 3.2 – 3.5) and b) problems in learning statistics (sections 3.6 – 3.7).

3.2 Suitability of Teachers

One of the main problems in teaching statistics is a lack of suitable and qualified teachers. For example in the United Kingdom, Starkings (1993) mentions that the statistics teacher is a rare commodity as there have not been any teachers specifically trained to teach it until fairly recently. Hawkins (1993) also points to the same problem that few graduates in statistics, if any, take up school teaching posts as a profession.

Teachers teaching mathematics in primary schools are normally generalists and are often not familiar with the contents and pedagogy of statistics. They might have never been exposed to statistics during their pre-service courses. Few, if any, have taken a methodology course covering the teaching of the subject. Hence, many concepts in statistics are alien to many of them. Even seemingly simple concepts like the arithmetic mean and other measures of location appear to be only partially understood by teachers and their young pupils alike (Russell and Mokros, 1991). Hawkins (1993) reports that about one third of the primary school teachers in UK had had no training in statistics beyond school level. The same situations are reported in many other countries (Aksu, 1993; Morin, 1993).

Since statistics has to be taught within the mathematics curriculum in secondary schools, the responsibility for teaching it falls on the mathematics teachers. Although a great majority of secondary school teachers, for example in England or Malaysia, who teach mathematics are graduates from the universities and might have attended a course in statistics and probability, they might not be competent or confident enough to teach statistics effectively. Some prominent statistics educators argue that mathematics-trained teachers might be less well equipped to teach the practical aspects of statistics and they might not easily be able to establish the necessary empathy with the less mathematically inclined students (Moore, 1988). Hawkins (1993) sums up the suitability of teachers teaching statistics in her survey: '*... a substantial proportion of the teachers surveyed were not particularly well-equipped to teach the statistics that was demanded of them, either because their background training was inadequate or inappropriate, or because their understanding of the real nature of statistics was weak, or because they were not sufficiently committed to the subject to appreciate and to respond to the way it was developing*'.

At tertiary level, there are perhaps no problems of unsuitable or unqualified teachers or lecturers teaching the various statistics courses including the introductory statistics course. Although most of the teachers/lecturers are highly qualified academically and can be regarded as statisticians, many of them lack the necessary teaching skills to teach effectively. Unlike school teachers, most teachers/lecturers at tertiary level do not have to take up a course in pedagogy in order to qualify to teach at that level. As such, statistics lecturers may be slow to practise what the statistics educationalists preach (Hawkins et al., 1992).

3.3 Teachers' Attitudes toward Statistics

A teacher's attitude towards statistics will also give some indication of his or her suitability to teach the subject. Due to lack of confidence or incompetence in teaching statistics, some mathematics teachers might avoid teaching it altogether, if possible. These teachers might feel that they could survive without learning and teaching statistics (Farrag, 1993). Even if they are required to teach the topic or the subject, they might not enjoy teaching it and would just treat statistics as just another topic in the mathematics syllabus. According to Hawkins (1993), these teachers would have failed to inform students what statistics is about and to impart the vitality and wide range of applications of the subject.

In Germany, Steinbring (1987) reports that, despite the many convincing reasons in favour of introducing statistics into junior secondary school, many mathematics teachers are still not willing to teach statistics. According to Steinbring, most teachers believed that statistics forms a completely different type of mathematics. To these teachers, the epistemological status of statistics which involves indeterminism is strange to them and contradicts the deterministic nature of mathematics with which they are familiar.

In a survey conducted by Gal (1993) in the USA, many high school and middle school mathematics teachers were also found to be reluctant to consider teaching statistics in their classes because of their negative attitudes towards statistics and a lack of confidence in their statistical knowledge. Gal speculates that this is mostly due to poorly taught college statistics courses that these teachers had taken that emphasised computation over understanding and did not afford learners opportunities to apply what they were studying.

The situation in the United Kingdom is however, quite to the contrary. Hawkins (1993) mentions that most of the respondents (mathematics teachers in UK) in her survey claimed to enjoy teaching statistics. However, many teachers in primary and lower secondary levels were found to dislike teaching probability or tended to see it as not applicable. To Hawkins, these negative views on probability are likely to perpetuate a weak representation of what statistical inference really involves. Hawkins also stresses that for the successful implementation of statistics teaching and learning in schools, it is necessary for teachers to change attitudes and expectations about statistics education. The findings by Gattuso (2002) in Italy also reflect that of Hawkins's. Although mathematics teachers in Italy are generally favourable towards statistics, they are, however, not in favour of allowing more time for statistics at the expense of other topics in mathematics.

3.4 What to Teach?

The present situation in primary and secondary schools in many countries is that statistics is taught within the mathematics curriculum under headings such as 'handling data' (eg. England and Wales), 'information handling' (eg. Scotland), 'data analysis' (eg. USA and France), or just simply 'statistics' (eg. Malaysia). In Malaysia, for example, the contents of the statistics strand within the mathematics syllabus normally include

a) presenting and interpreting discrete data in the forms of frequency tables, pictographs, pie charts and bar charts
b) presenting and interpreting continuous data in the forms of grouped frequency tables, frequency polygons, histograms and graph of cumulative frequency
c) calculating the 'averages'
d) calculating the measures of dispersion and
e) introduction to probability

At primary level, only a) and c) are taught while at the secondary level all are included (Curriculum Development Centre (Malaysia), 2002). Apparently, what is taught in Malaysia currently is basically more or less the same as in other countries (see for example Teran (1998)).

3.4.1 What to Teach at Primary Level?

What kind of statistics is appropriate to be taught at school levels? Apart from presenting and interpreting discrete data and calculating the 'averages', students at primary level should also learn how to collect real data themselves. Many studies (e.g., Galmacci and Milito (2002); Dunkels (1993)) have shown that working with real data reflecting real-life phenomenon favours a better learning of statistics and develops students' interests as they are personally involved in the collection and interpretation of data. This activity of collecting real data could begin in the classroom itself like collecting and recording data on pupils' height, weight and how much pocket money they get per week. Later, teachers could expose the pupils to exploratory data analysis, an approach which Tukey (1977) describes as '*...about looking at data to see what it seems to say. It concentrates on simple arithmetic and easy to draw pictures. It regards whatever appearances we have recognised as partial descriptions, and tries to look beneath them for new insights*'. One easy-to-draw picture that is suitable for primary level is the stem-and-leaf display which is suitable for small data sets. Dunkels (1993) mentions the many uses of stem-and-leaf plots such as a mean of displaying the distribution of the data, as a thought starter as well as an instrument for showing how the place value system (units, tens, hundreds, etc.) works with numbers. Students could also comment on the overall shape of the distribution, the approximate centre of the distribution and any deviations from the overall shape. As a matter of fact, the concepts of 'mode' and the 'median' could also be introduced without doing any calculation.

The ideas of probability should also be taught in primary schools. In England and Wales, this has already happened where students are taught to develop an understanding of probability through classroom situations and discuss events using vocabulary such 'likely', 'unlikely', 'fair' and 'certain' (QCA, 1999). Holmes (2002) argues that primary school children can learn and enjoy elementary probability (see also Fishbein (1975)). Fishbein (1990) also mentions various research carried out by educational psychologists that revealed the ability of children to express correct probabilistic judgements in simple situations. Fishbein (1990) further points out that by deferring the teaching of probability until secondary school level, accompanied as it is by an over emphasis on determinism, may damage existing probabilistic skills and/or impede the subsequent learning and understanding of probability. He also finds decrements in probabilistic performance with increasing age which he attributes to school experience and to scientific reductionism (see also Fishbein and Schnarch, 1997). Berrondo-Agrell (2002) tells of her success in teaching probability to ten-year-old children based on reasoning with images. Li and Pereira-Mendoza (2002) tend to agree with Fishbein's finding when they conclude from their study in China that Chinese students' understanding of probability does not improve naturally with age. The concept of randomness in probability can also be introduced to primary school children as shown by Green (1987, 1989) in his study of school pupils' understanding of randomness. So, there is no reason why lessons on probability should be denied to primary school children. However, as reported earlier, primary teachers (for example in UK) seem to have negative attitude towards teaching probability. Perhaps they think of probability concepts as being difficult to understand not only to the primary pupils but also to themselves. Therefore, as probability is quite a difficult concept to teach or to learn as well as a lot of misconceptions attached to it (see section 3.7.2), teachers should be properly trained to teach it so as not treat it as just another topic in mathematics.

3.4.2 What to Teach at Secondary Level?

In the secondary school, students are normally taught how to present continuous data graphically by constructing a histogram that shows the centre, the spread and the skewness of the data as well as the presence of outliers. Other important graphical displays for continuous data in exploratory data analysis that should be taught are the boxplots and the scatterplots. A boxplot provides a good summary of the data which consists of the five-number-summary namely, the minimum value, the first quartile, the median, the third quartile and the maximum value (Aliaga and Gunderson, 1998). Students could also use side-by-side boxplots to compare two or more distributions. When investigating the relationship or association between two variables, students could use the scatterplots (Aliaga and Gunderson, 1998). Then, they should be taught to have a basic understanding of correlation as a measure of the strength of the association between two variables and to identify correlation or no correlation using lines of best fit (QCA, 1999). It is also important to point out to students that 'correlation does not imply causation' by giving examples.

In lessons on probability where the focus is always on theoretical probability based on equal likelihood, secondary school students should also be introduced to relative frequency probability obtained empirically and subjective probability based on personal judgements. Students should use relative frequency as an estimate of probability and understand that if they repeat an experiment, they may and usually will get different outcomes, and that increasing sample size generally leads to better estimates of probability (Costello, 1991). Students should also be made to realise that sometimes relative frequency and equally likely considerations might not be appropriate when assigning probabilities to certain events and hence, subjective estimates have to be made. Many research studies in statistics education have shown that students tend to have subjectivist viewpoints concerning events surrounding them (e.g.; Falk, 1989; Konold, 1991; Garfield and Ahlgren, 1988; Richardson and Haller, 2002). Therefore, students should be taught when and why it is appropriate to use equal likelihood or relative frequency or subjective estimates to determine a probabilistic value for the occurrence of any event.

Finding a probability by simulation can also be introduced to students. According to Aliaga and Gunderson (1998), a simulation is the imitation of random or chance behaviour using random devices such as number generators or a table of random numbers. The basic steps for finding a probability by simulation are

a) specify a model for the individual outcomes of the underlying random phenomenon
b) outline how to simulate an individual outcome and how to represent a single repetition of the random process and
c) simulate many repetitions and estimate the probability of an event by its relative frequency.

Other areas of statistics that should to be taught to secondary school students are how to collect data through questionnaires and surveys designed by the students themselves, gathering data from secondary sources including printed tables and lists from information and communication technology (ICT) based sources as well as interpreting social statistics including index numbers (for example, the General Index of Retail Prices); time series (e.g., population growth); and survey data (e.g., the census) (QCA,1999).

Students should also be exposed to abuse and misuse of statistics. They should also be made to realise that misuses of statistics could affect human decision-making processes which in turn affects the course of human lives (Shaughnessy, 1981). It can be argued that one of the main objectives of teaching statistics should be to enable students to understand statistics as a language so they can detect the statistical doublespeak (abuse and misuse of statistics) they encounter in the media as well as in their fields of study.

3.4.3 What Should be the Contents of Introductory Statistics Course at Tertiary Level?

The introductory statistics course at tertiary level normally adopts the traditional syllabus structure to be covered in one or two semesters as shown in Figure 3.1 below:

Descriptive Statistic → Probability → Inferential Statistics

Fig. 3.1 Introductory statistics course structure

Borovcnik (1985) lists the contents of a typical introductory statistics in most colleges in the USA, as shown in Table 3.1 below:

Descriptive Statistics
1. Measures of central tendency (mean, mode, median) 2. Measures of variability (range, variance, standard deviation) 3. Measures of position (percentile, z-scores) 4. Frequency distributions and graphs
Probability Theory
1. Rules (addition, multiplication) 2. Independent and mutually exclusive events 3. Random variables 4. Probability distributions 5. The binomial distribution 6. The normal distribution 7. Sampling 8. Central limit theorem
Inferential Statistics
1. Estimating parameters (mean, variance, proportion, correlation coefficient) 2. Testing hypotheses

Table 3.1 Typical introductory statistics course syllabus

Hawkins *et al.* (1992) list several deficiencies of the above structure:

a) the three components tend to become compartmentalised and generally a poor balance is struck between them
b) little time may be devoted to descriptive statistics and the time that is given to it, generally focuses on the mechanics of artwork and of computing summary measures
c) teachers and lecturers skim through basic probability early on in the syllabus in order to proceed to inferential statistics and
d) inferential statistics is taught based on a type of probabilistic reasoning which apparently bears little or no relationship to the computational/algorithmic laws of probability encountered earlier.

Meletio and Lee (2002) also express similar views when they stress that '*...presenting statistical content as a sequenced list of curricular topics might lead to compartmentalisation of knowledge and fail to communicate to students the interconnectedness of the different statistical ideas they encounter in the course.*'

Snee (1990) suggests that an introductory statistics course must place greater emphasis on matters such as data collection, graphical display of data and understanding and modelling variation but less emphasis on mathematical and probabilistic concepts. Only the necessary probabilistic concepts for further statistical thinking should be taught (Moore, 1992). Cobb (1993) proposes that in a beginning course in statistics at tertiary level, statistical thinking should be taught with more real data and concepts but with less theory and fewer recipes. Cobb also suggests that the course

a) needs not be organised by statistical topic
b) needs not have to present topics in the standard order and
c) needs not have to rely on lectures to present materials.

Utts (2002) identifies three factors which would make the traditional teaching of introductory statistics course redundant namely:

a) the audience – broader set of majors represented and greater age mix
b) the tool for students – universal access and use of calculators and computers and
c) the world around us – many more studies reported in the news, abundance of examples available on the internet and journal articles available on-line.

It can be argued that the consequence of all these changes is that students have less need to do calculations and more need to understand how statistical studies are conducted and interpreted. Utts suggests that introductory courses in statistics should also focus more on areas which are found to be commonly misunderstood such as biases in surveys, cause and effect, difference between statistical significance and practical importance, probable and improbable coincidences, cycles and trends and confusion between average and normal.

3.5 How to teach?

One of the main problems in teaching and learning statistics is that teachers often have the somewhat erroneous view of statistics as being part of mathematics although it is generally acknowledged that statistics is a discipline that makes heavy and essential use of mathematics (Moore, 1997). According to Meletio and Lee (2002), this view affects statistics instruction and hampers the reform efforts in statistics education. Teachers need to realise that statistics has its own subject matter and they should also know the differences between the two disciplines (statistics and mathematics) as mentioned earlier in Chapter Two. Thus, the approach towards teaching these two disciplines should be different too.

As Gilchrist (1987) points out, statistics, if properly taught, should be inductive while the teaching of mathematics is mainly deductive. When using the inductive method, a number of particular examples would be considered, common properties would be noted and a generalisation would be stated which would be likely to be true for all other similar examples. On the other hand, the deductive method involves the use of formulas, rules or theorems to solve specific problems and to produce unique answers.

The traditional style of teaching statistics (mainly the deductive method) with much emphasis on giving students rules and techniques to memorise and drill set for practising algorithms is still being employed in many schools around the world (e.g. Milito *et al.*, 2001). More than twenty years ago, the Cockcroft Committee (1982) also criticised the way statistics was taught in secondary schools at that time: '*...too much emphasis is very often placed on the application of statistical techniques, rather than on discussion of the results of ordering and examining the data and on the inferences which should be drawn in the light of the context in which the data have* *been collected. The work can therefore become dry and technique-oriented and fail to show the power and nature of statistics.*' This view is also supported by Maher and Pancari (1993) who opine that '*...to teach statistics in the traditional way with concepts presented using 'unreal world' situations and examples is often boring and thoughtless, hardly motivating to learn and failing to capture the essence of its use'*.

Students attending the introductory statistics courses for non-majors in colleges and universities often resort to memorising and manipulating statistical formulas and rules in order to pass the course (Riggs, 2003; Ramsey, 1999). Ramsey (1999) further describes how the memorised formulas are then inserted into so called 'problems' for which rules of thumb have been developed to know which formula is to be plugged into which problem. Riggs (2003) points out that this is mainly due to the traditional method of 'lecturers telling and students listening and writing', the lecture style which tends to dominate these courses. There is a joke about teaching statistics in this manner that information passes from the lecturer's to the students' notes without passing through the minds of either party! (Taffe, 1987 & 1991). According to Harkness *et al.* (2003), the main weaknesses of this traditional format of teaching introductory statistics course are

a) it fails to address the broad range of differences in student learning styles and quantitative skills
b) it does not encourage active participation
c) students are unable to apply statistics in follow-up courses
d) students developed negative attitude towards statistics
e) students' retention of subject matter appears to be short

Despite the shortcomings of the traditional methods of teaching, educators continue to use them in teaching statistics and other subjects. Why is this so? The pressure to cover the syllabus on time and to prepare students well for examination can lead teachers to teach to the test. This means that, in statistics, the emphasis would be on teaching the techniques and relegating the global views of the importance of statistics as well as the nature of statistical thinking to the sidelines. According to Stephens and Izards (1992), what is assessed exerts a powerful influence over what and how a subject is being taught. Good results from examinations are valued highly by students, teachers, parents and the community. In statistics, students would rarely expect to be assessed on conceptual understandings. Instead, computational techniques tend to predominate (Cheung, 1990). At the tertiary level, lecturing and with the backing up by tutorials has been seen as an efficient strategy to deliver the content of a large syllabus in short amount of time (Martin, 1991). This is especially true in introductory statistics 'service' course with a high enrolment which can reach up to 300 students per class!

By its very nature, the study of statistics provides students with many opportunities to describe, organise and summarise data so that they can make greater sense of collections of quantitative information. Thus, what should be the appropriate method or methods to teach statistics effectively? There is no doubt that teaching some skills in statistical computation are valuable. Nevertheless, the emphasis must be on the understanding of the problem presented by the data, selecting suitable techniques and interpreting the results of the statistical analyses. With the availability of graphic calculators and computer spreadsheet packages in most schools or colleges and students having access to them, performing the calculation of various statistical analyses manually should be a thing of the past. The graphic calculators and computer spreadsheet packages can also be used to help students especially in secondary and tertiary levels to construct the various graphical displays.

Burrill (1993) argues that the focus in teaching statistics should be to foster students' belief about the positive use of statistics in making choices and decisions. To achieve this, she suggests the following strategies:

1. *Activities for students should be active, asking questions about something in their environment and finding quantitative ways to answers them.*
2. *The emphasis in all work should be on the analysis and the communication of this analysis in contrast to a focus on a single correct answer.*
3. *Different approaches and solutions for a problem should be discussed and evaluated with opportunities provided for student reflection.*
4. *Real data and hands-on experience in working with data should be used whenever possible.*
5. *Exploration and experimentation should precede formal algorithms and formulas.*
6. *Good examples should be used to build intuition rather than the use of paradoxes to deceive.*

7. *Student projects should be an integral part of any work in statistics.*
8. *Statistics should be a vehicle to make connections within mathematics and to form interdisciplinary links for students.*
9. *Technology should be used to facilitate analysis and interpretation.*
10. *A variety of approaches should be used for student assessment: reports. Projects, journals, student-generated tests as well as traditional assessments.*

The general idea encapsulated by the strategies described above is that students must be active participants in constructing their own statistical knowledge. Students' learning tends to improve if they are actively involved in the learning processes (Breslow, 1999). Many professional bodies such as the American Statistical Association and the Mathematical Association of America have promoted the active learning model when teaching statistics (Riggs, 2003). Siberman (1996) defines active learning as studying ideas, solving problems and engagement in some activity that encourages students to think and apply what is learned.

Riggs (2003) lists four main strategies (which are quite similar to some of Burrill's strategies described above) as the recommended components of active learning namely:

a) collaborative learning - small group activities where students are encouraged to discuss concepts and verbalise their ideas.
b) hands-on activities - to help students develop conceptual understanding by using concrete versions of abstract ideas.
c) student projects - the most effective way of supporting student synthesis of the course material as students must talk about statistics, apply concepts and principles learned in class and relate them to the research questions in their projects.
d) the use of technology - calculators, computer software, databases and internet web sites can invigorate the statistics classroom with the students as active participants.

Teachers should also look into teaching statistics using various other strategies such as 'striking demonstration' method (Sowey, 2001), using humour (Friedman et al., 1999; Friedman *et al.*, 2002)) and using analogies and heuristics (Martin, 2003). According to Sowey (2001), 'striking demonstration' is any proposition, exposition, proof, illustration, analogy and application that has the following characteristics:

a) it is sufficiently clear and self-contained to be immediately grasped
b) it is immediately enlightening though it may be surprising
c) it arouses curiosity and/or provokes reflection and
d) it is so presented as to enhance the impact of the foregoing three characteristics.

It can be argued that using humour in the statistics classroom can strengthen the relationship between student and teacher, reduces stress, makes a course more interesting and if relevant to the subject, may even enhance recall of the material.

3.6 Students' Beliefs and Attitudes in Learning Statistics

What are beliefs and attitudes in learning statistics? Much has been said about what students' beliefs and attitudes are towards mathematics. For example, McLeod (1992) describes what 'emotions', 'attitudes' and 'beliefs' are in conceptualising the affective domain of mathematics education. In applying McLeod's terminology, Gal *et al.* (1997) endeavour to describe what beliefs and attitudes are in statistics education. They agree that beliefs that would be important to consider by teachers of statistics may include

a) beliefs about statistics (e.g., is it easy or hard, require innate skills, it can be mastered by anyone)
b) beliefs about the extent to which statistics is part of mathematics or requires mathematical skills (e.g., statistics is all computations)
c) beliefs about what should happen or transpire in a statistics classroom, or expectations as to the culture of a statistics classroom (e.g., a lot of drill and practice with textbook problems, a lot of talking about real-world examples)
d) beliefs about oneself as a learner of statistics (e.g., I am good at it, I don't have what it takes)
e) beliefs about the usefulness or value of statistics and its importance in one's future life or career (e.g., I will never use it and don't really need to know it).

They also hold the opinion that beliefs take time to develop, are stable and quite resistant to change, with a larger cognitive component and less emotional intensity than attitudes.

Meanwhile, attitudes towards statistics as described by Gal *et al.* (1997), represent a summation of emotions and feelings experienced over time in the context of learning statistics. They also believe that attitudes are quite stable with moderate intensity expressed along a positive-negative continuum, and have a smaller cognitive component than beliefs and may represent, for example, feelings towards a topic, a textbook, a project or activity, a teacher or the school. Despite the distinctions between 'beliefs' and 'attitudes' as just described, McLeod (1992) argues that 'attitudes influence and are influenced by one's own beliefs'.

According to Gal *et al.* (1997) it is important that the assessment of students' beliefs and attitudes towards statistics be carried out before, during and after taking a statistics course. They mention three reasons why students' attitudes and beliefs regarding statistics deserve attention:

a) their role in influencing the teaching and learning process
b) their role in influencing students' behaviour in statistics after they leave the classroom and
c) their role in influencing whether or not students choose to pursue further studies in statistics.

Students' beliefs and attitudes towards learning mathematics or science are known to be related to their success or failure (e.g. Ma & Kishor, 1997 (in mathematics); Osbourne *et al.*, 1998 (in science)) This is also true in the case of statistics. Many of the difficulties encountered by students in statistics courses may not be a result of insufficient aptitude, rather they may be reflections of attitudes and beliefs (Baloglu, 2001; Gal and Ginsburg, 1994). A survey of research studies mentioned by Garfield *et al.*, (1999) indicated the existence of small to moderate relationship between students' attitudes and their performance in statistics. Del Vecchio (1994) reports that students who expressed more confidence in their abilities to do statistics were more likely to complete their course with a passing grade.

Phillips (1990) and Nooriafshar (2002) report that many students in Australian high schools and colleges who are required to study statistics, give the impression that they are not keen to study it and tend to look upon the statistical component as an unpleasant requirement of their course. In the USA, students who do not major in mathematics and/or statistics often view statistics as the worst course taken in college (Iman, 1994; Hogg, 1991). To these students, statistics is a required 'math' course they have to take and they are fearful of taking it because they are not comfortable with their mathematical and computational ability (Albert, 2002). Broers (2002), from The Netherlands, laments the fact that students from non-mathematical background often show avoidance behaviour when confronted with statistics and frequently display a lack of motivation in statistics classes no matter how much effort teachers invest in making their teaching accessible and lively. Various descriptions of statistics as being boring, a waste of time and not relevant are not uncommon (Hollis, 1997).

Gal *et al.* (1997) refer to several comments written by high school and university students in the USA who had not learned statistics before. They suggest that students may enter statistics education at either secondary or tertiary levels with strong feelings or beliefs involving this subject. These strong feelings are either positive or negative. Negative attitudes or beliefs can impede learning of statistics, or hinder the extent to which students will develop useful statistical intuitions and apply what they have learned outside the classroom (Gal and Ginsburg, 1994). These negative attitudes or beliefs may originate from the mathematics learning experience students encountered previously in school. Simon and Bruce (1991) point to the fact that attitudes and beliefs related to mathematics may play a powerful role in affective responses to statistics. These students often expect that the study of statistics to include a heavy dose of mathematics such as complex algebra and calculus. Gal and Ginsburg (1994) hypothesise that if students experienced difficulties and frustrations with their mathematical studies in school, similar processes could happen in their statistical studies as well.

In statistics education, several instruments used to assess attitudes toward statistics could be found in the literature such as Attitudes Toward Statistics (Wise, 1985) and Survey of Attitudes Toward Statistics (SATS) (Schau *et. al.*, 1995). These instruments use statements for which respondents mark their agreement or disagreement on 5-point or 7-point Likert-type scales. According to Schau *et. al.*, a good instrument should include items

- that measure key factors of statistics attitudes such as 'affect', 'cognitive competence', 'value' and 'difficulty'. (these factors are identified from factor analysis of items in some statistics attitude surveys)
- that are based on input from the students who will complete the survey.
- that are short and so minimally disruptive when administered in the classroom.
- that measure both positive and negative attitudes.

The SATS developed by Schau *et. al.* consists of 28 seven-point Likert-type items measuring four aspects of students' statistics attitudes as determined from factor analysis: affect (6 items), cognitive competence (6 items), value (9 items) and difficulty (7 items). Total scores are then obtained by summing up all the items together to determine a student's statistics attitudes. Scoring for negative items should be reversed (1 becomes 7, 2 becomes 6 etc) before obtaining the total scores. Higher total scores will then correspond to more positive attitudes. However, some researchers do not recommend this system of summing up all the items' scores. For example, Reid (2003) points out that '*...Adding up a set of such scores may give a number but that number may be fairly meaningless and all the interesting patterns of responses for individual questions are lost*'

It is also worth mentioning the statistics anxiety which is an attitudinal factor common to many students entering introductory statistics courses. Cruise *et al.* (1985) defines statistics anxiety as the feelings of anxiety encountered when taking a statistics course or doing statistical analyses; that is gathering, processing and interpreting. Many research studies have shown that older students experienced more statistics anxiety than their younger counterparts (e.g. Onwuegbuzie (1998); Royce and Rompf (1992)). Perney and Ravid (1991) describe how college professors teaching statistics encountered students exhibiting high level of anxiety on the very first day of attending class! Perhaps, those were not isolated incidents but could well describe a typical scenario in any introductory statistics class at the beginning of the semester or term.

It can be argued that statistics anxiety is an appropriate response when certain beliefs are present. Carter and Yackel (cites in Gal & Ginsburg, 1994) give an example of the relationship between beliefs and anxiety in mathematics education: '*...if an individual believes that mathematics is a collection of rules and procedures, then success in* *mathematics is determined by one's ability to memorise the rules and procedures and produce them at appropriate moments in the problem-solving process. For routine exercises and practice problems, this belief system allows success and comfort. If an appropriate rule or solution path is not apparent during a problem-solving situation, however, then the learner is at a standstill since there is no mechanism in place for modifying and/or developing rules or procedures. This situation causes feelings of panic, inadequacy and anxiety...'* This example could also apply to individuals who are studying statistics with similar beliefs and experiencing similar anxiety. Investigating students' beliefs about statistics and describing the ways in which they learn and understand statistics will enable teachers and lecturers to develop suitable curricula that focus on enhancing student learning environment and to positively affect statistical anxiety and attitudes towards statistics (Reid & Petocz, 2002; D'Andrea and Waters, 2002)

3.7 Difficulties in Learning Statistics

Over the past thirty years, many researchers including psychologists and statistics/mathematics educators have carried out studies related to learning and understanding statistics. However, many of the studies have concentrated on the areas of probability (e.g. Kahneman and Tversky, 1972; Tversky and Kahneman, 1973 & 1974; Fischbein, 1975; Fischbein and Gazit, 1984; Green, 1982; Konold, 1991). According to Shaughnessy (1992), psychologists whom he describes as observers/describers, generally focus their research on how probabilistic reasoning (judgement and decision making) occurs in situations of uncertainty and then attempting to explain what they observe on the basis of some theoretical models. On the other hand, statistics/mathematics educators are 'natural interveners' (Shaughnessy's description) such that they have the intention to improve students' knowledge of statistics and also to change the latter's conceptions and beliefs.

Most researchers believe the difficulties in learning and understanding statistics that students encounter are due to two reasons. Firstly, some statistical concepts are found to be intrinsically difficult because they are unlike anything students have thought of before and secondly, certain statistical concepts encounter interference with intuitive ideas that students already have (Garfield and Ahlgren, 1987). Statistics educators often refer to these intuitive ideas as misconceptions. Statistical misconceptions especially in probability are difficult to eliminate, as they appear to be of a psychological nature and are strongly resistant to change (Shaughnessy, 1977; Konold, 1991 & 1995). Konold (1995) explains that students are often able to assimilate new information they learn in the classroom into their existing beliefs and misconceptions, or they alter new information so that it is consistent with their current understanding and consequently, they continue to hold misconceptions.

In the following subsections, difficulties and misconceptions in descriptive statistics and probability will be discussed in turn.

3.7.1 Difficulties and Misconceptions in Descriptive Statistics

Hawkins *et al.* (1992) point out that the terms 'population' and 'sample' often caused problems to a new student. In the statistical context, 'population' refers to the entire group of objects or individuals under study and about which information is wanted while 'sample' refers to a part of population that is actually used to get the information (Aliaga and Gunderson, 1998). However, to a beginning student in statistics, the former refers to people living in the same area (village, city, country or continent) and the latter is used in such contexts as a sample survey, free samples of consumer goods and samples of blood and urine in medical research (Hawkins *et al.*, 1992). Hawkins *et al.* further describe how '*...the ideas underlying the descriptions of samples and populations become more confused when the student is faced in classical inference with data from two or more samples, known to have been meticulously drawn from the same population... but about which the inference procedure suddenly requires judgements about whether or not they are likely to have been drawn from the same population*'.

Vallecillos and Moreno (2002) conducted a study about Spanish secondary students' conceptions about samples and populations and their relationships. In this study, they observe that

a) some students are confused about the ideas of 'sample' and 'population'
b) some students believe that the characteristics of a population can only be described by doing a census and not by studying samples extracted from it and

c) some students do not take into consideration the sample size when making estimation for a population characteristic.

Landewehr (1989) mentions several other misconceptions students have regarding sample and population such as

a) unwarranted confidence in small samples
b) insufficient respect for small differences in large random samples and
c) the size of sample should be directly related to the population size

Difficulties related to types of data, frequency tables and graphical representations of data have also been reported in many studies. Gardner and Hudson (1999) report how some students in their introductory statistics course display difficulty in determining whether data in a hypothetical research problem are nominal (categorical), ordinal or interval/ratio. Pereira-Mendoza and Mellor (1991) discover some severe problems associated with primary students' conceptions in bar graphs such as

a) difficulties with interpreting the questions posed due to computation errors, reading/language errors and scale errors
b) difficulties in making predictions solely based on the graphs and
c) the tendency to think that patterns must exist in a graph although sometimes it is not necessarily the case

Secondary students also show misconceptions about graphical displays such as the incorrect choice of graphs when presenting data, the axes on the graphs are not labelled properly, the origin of coordinates is not specified and the chosen scales are inadequate especially when graphs are drawn by using graphical software (Li and Shen, 1992). Batanero *et al.* (1994) caution about the inappropriate use of software such as when using a pie chart where the sectors are not proportional to the frequencies in the categories. In a tabulated frequency distribution, some students often find it difficult to make a distinction between observations on a variable and the frequencies of those observations (Hawkins *et al.*, 1992). This can cause problems when determining median and mode from the frequency tabulation when students choose the middle frequency as the value for median and the largest frequency as the value for mode instead of the appropriate observations (Barr in Hawkins *et al.*, 1992).

Garfield (2003) identifies misconceptions involving averages from the outcomes of the Statistical Reasoning Assessment (SRA) in USA such as

a) averages are the most common number
b) to find an average, one must always add up all the numbers and divide by the number of data values (regardless of outliers)
c) a mean is the same as a median and
d) one should always compare groups by focusing exclusively on the differences in their averages.

These findings ((a) to (c)) seem to concur with that of Russell and Mokros (1991). Landewehr (1989) discovers that people have the misconception that any difference in the means between two groups is significant, which is quite similar to (d) in Garfield's finding. Although the concept of mean seems straightforward, Hawkins *et al.* (1992) find that students tend to use a mechanistic approach like combining two weighted means as if they were simple arithmetic means when faced with an example like the following item below (see also Pollatsek *et al.*, 1981; Batanero *et al*, 1994):

There are eight big male students and four slim female students in a lift. The average weight of the male students is 90kg and the average weight of the female students is 50kg. What is the average weight of all the students in the lift?

Batanero *et al.* (1994) point out that the situations like the above example in which a weighted mean must be computed are not easily recognised by students. In trying to answer the example in Table 3.2, students might think that it is possible to 'average the averages' by the 'add them up and divide' algorithm (Mevarech, 1983). Batanero *et al.* (1994) also mention how the study of order statistics (involving median, quartiles and percentiles) presents computational and conceptual difficulties to students. Students are taught to use different algorithms for non-grouped data and data grouped in intervals. Batanero *et al.* also points out to the large gap between the conceptual knowledge of the median and the algorithm employed to get its value.

Studies have shown that students know how to compute standard deviation but do not really understand what it means (e.g. Meletio *et al.*, 1999). It is really an unfortunate situation since the notion of variation with its related measures variance and standard deviation is the central element in statistical thinking, which is in turn is concerned with learning and decision-making under uncertainty (Meletio and Lee, 2002; Wild and Pfannkuch, 1999). Landewehr (1989) mentions that people inappropriately believe that there is no variability in the 'real world' because they do not believe in random events or chance. In their study, Pfannkuch and Brown (1996) also arrive at similar conclusion that some students lack awareness or understanding of variation.

According to Hawkins *et al.* (1992), the almost immediate introduction of the formula of variance seems to be the barrier to the ready acceptance of the idea of variation. Students are distracted by the seemingly difficult formula with the squared deviation and the divisor which is either n or $n-1$ rather than concentrating on understanding what the concepts of variance and standard deviation are about. It should also be noted that the formula for variance is not just in one form but has several forms including for the grouped frequency distribution. This conveys no meaning to many students about arguably the most important concept in statistics (Hubbard, 1991). According to Mevarech (1983), some university students experience difficulties in understanding the calculation of variance. They also wrongly assume that group structure properties like associativity and closure apply to the computation of variance. In a study about variation conducted on psychology students with no experience of learning statistics, Loosen *et al.* (1985) discover that the students' intuitive concept of variability is more concerned with how much a set of values differ from each other rather than from some fixed value like the mean.

3.7.2 Difficulties and Misconceptions in Probability

As mentioned in Chapter Two, one definition of statistics is that it is the systematic study of uncertainty, and probability is the only sensible measure of uncertainty. As Lindley (1991) points out: '*The core concept, around which all statistics teaching should be based, is probability*'. Although on one hand, the notion of probability is deemed very important in statistics since it encourages the use of different or broader kinds of reasoning and tools which are essential in mathematical modelling; on the other hand, it is also regarded as a particularly difficult concept to teach and learn due to its dealing with uncertainty (Shaughnessy *et al.*, 1996). Konold (1991) uses the term '*slippery*' to describe the difficulties in understanding the concept of probability and he warns that '*...like a frictionless surface, the conceptual landscape not only trips you up, but keeps you sliding once you're down*'.

Students come to learn probability with their own experiences and intuitive ideas and this would lead to conflict with the probability taught in school (Kapadia, 1985). These intuitive ideas include their weak understanding of the common language of probability such as 'at least', 'unlikely', 'least likely', 'certain' and 'impossible' (Green, 1982). According to Konold (1995), these intuitive ideas might prove difficult to change and trying to change them is complicated due to students' ability to hold multiple and often contradictory beliefs about a particular situation. However, recent research findings by Cosmides and Tooby (1996) and Pfannkuch and Brown (1996) mention that students do have a basis for correct probabilistic thinking when teaching approaches build on students' intuitive ideas. Falk and Konold (1992) believe that the very basic difference between formal and informal views of probability concerns the perceived objective in reasoning about uncertainty. The former is concerned with deriving measures of uncertainty while the latter is more concerned with predicting outcomes. The latter is also referred to as the 'outcome approach' to probability (Konold, 1989). Acccording to Konold, an outcome-oriented student uses a 50% chance as a guide to deciding a certain 'yes' and a certain 'no'. Falk and Konold (1992) give anecdotal evidence of how children interpret the value of probabilities they encounter in a game where probabilities greater than 0.5 are 'sure to win' and those below 0.5 are 'sure to lose'. A recent study by Li and Pereira-Mendoza (2002) in China also points to the 'outcome approach' misconception as a source of difficulty in learning probability.

Before discussing misconceptions in probability in more detail, perhaps it is appropriate to mention about the concept of randomness because probability is the study of randomness (Moore, 2001). Various dictionary definitions of randomness emphasise the idea of 'apparent absence of cause, design or planning' or simply 'accidental or haphazard' but Moore (2001) disagrees with those definitions. He thinks of randomness as relating to phenomena that have uncertain individual outcomes but have a regular pattern of outcomes when investigated over many repetitions. Over the years, many psychologists have carried out research on the misconceptions of randomness using mainly sequences as stimuli and the conclusion is that human beings are incapable of perceiving randomness (Falk and Konold, 1998). According to Falk and Konold, the psychologists identify the following misconceptions:

a) convinced that there was a pattern in the stimuli, the subjects believed that the oncoming event depended on the preceding ones
b) people identify sequences with an excess of alternations as most random while truly random sequences that contain the modal number of runs are judged as less random because the runs appear too long to appear by chance.

In a survey of students' understanding of randomness in England, Green (1987, 1989) finds that the students are poor at distinguishing random from non-random distributions (in this case, the distributions of snowflakes) or in selecting the most random binary sequences of 0's and 1's from a list of hand-generated binary sequences. Green (1989) also discovers that performance in recognising randomness declines with age due to a dominance of scientific reductionism students experience in school which stifles the appreciation of randomness by seeking to codify and explain everything.

The research done by the psychologists Kahneman and Tversky in the early 1970's (1972, 1973, 1974) offers fascinating reasons on why people's judgement tends to differ and inconsistent with a correct technical understanding of probability. The psychologists try to categorise certain types of misconceptions of probability by the common judgemental heuristics used by people such as representativeness and availability (examples are given in the next paragraph). They further suggest that people use these heuristics due to their limited information processing capacity. Thus, these heuristics allow them to estimate complicated probabilities and to make decisions quickly. According to Konold (1991), these heuristics might give adequate estimates but could lead to predictable judgement errors in some situations due to the limitations in the amount and type of information to which the heuristics are sensitive.

The representativeness heuristic refers to the way people estimate the likelihood of a sample based on how well it resembles some characteristics of its parent population (Kahneman and Tversky, 1972). Gates (1991) describes this heuristic as the belief that each short sequence should be a representation of the long-term tendency. Gates gives an interesting example as follows:

Consider the following sequences of H's (head) and T's (tail). One of these was obtained when a fair coin was tossed 10 times – which one?

a) HTHTHTHTHH
b) HHHHHHHHHT
c) THTTTHHTHH
d) HHTTHHTTHH

Gates observes that people tend to opt for c) because it is the only sequence which involves an equal number of H's and T's. However, all the above sequences are possible and equally likely if the theoretical model for assigning probabilities is used (Shaughnessy, 1992). In fact, there are altogether 1024 (2^{10}) such sequences. Madsen (1995) agrees with the Gates's finding when he tested a similar item on students aged 13 to 19. Hirsch and O'Donnell (2001) conduct a study in identifying and assessing misconceptions in probability and the study reveals that representative heuristic is the most common one. However, after an intervention study, where the students were taught the correct concepts together with practical activities, they report that students' misconceptions appeared to be eliminated.

According to Garfield (1995), the use of this heuristic also leads to people to judge small samples to be as likely as large ones to represent the same population. For example, 60% heads is believed to be just as likely outcome for 1000 tosses as for 10 tosses of a fair coin. Shaughnessy (1992) also mentions how representativeness is used to explain the negative recency effect or 'gambler's fallacy'. For example, after observing a long run of tails, most people believe that a head is now due because the occurrence of a head will result in a more representative sequence than the occurrence of another tail. A related misconception is the 'hot hand fallacy' where people tend to think that repeating outcomes are caused by unseen forces and do not recognise them as being the result of a chance (Glovich, 1991; Albert, 2002).

Base rate fallacy is another misconception that is associated with representativeness where people choose to ignore the relative sizes of population subgroups when judging the likelihood of contingent events involving the subgroups (Tversky and

Kahneman, 1974; Bar-Hillel, 1980; Garfield, 1995). Shaughnessy (1992) provides an interesting example: '*... subjects may be told that a person is male, 45, conservative, ambitious and has no interest in political issues. Then, they are asked which is more likely the case: (a) the person is a lawyer, or (b) the person is an engineer'*. The survey subjects overwhelmingly choose (b) because the description above is not typical of a lawyer although subjects are told that the person in the description is randomly drawn from 30% engineers and 70% lawyers. According to Shaughnessy (1992), this base rate information does not have much effect on the subjects' predictions for the person's occupation.

Another judgemental heuristic investigated by Kahneman and Tversky (1972) is the availability heuristic when people tend to estimate the occurrence of an event based on how easy it is for them to recall the particular instances of the event. According to Shaughnessy (1992), this heuristic can bring on bias based on one's own experience and personal outlook because one tends to believe that outcomes that can easily be brought to mind will be more likely to occur. For example, people may determine the probability of winning a lottery by trying to recall people they know, or know of, who have won (Konold, 1991). Madsen (1995) presumes that this is one of the reasons national lotteries and football pools like to advertise using the names and photos of past winners. Shaughnessy (1981) presents several items that are used to assess students' reliance on availability prior to a course in probability, one of which is given below:

Consider the grids below.

Grid A	*Grid B*
XXXXXXXX	*XX*
XXXXXXXX	*XX*
XXXXXXXX	*XX*
	XX
	XX
	XX
	XX
	XX
	XX

Are there

a) more paths possible in grid A?

b) more paths possible in grid B?

c) about the same number of possible paths in each grid?
A path is carefully defined as a polygonal chain of line segments starting at the top row and proceeding to the bottom row and meeting one and only one symbol in each row.

According to Shaughnessy (1981) majority of students tend to choose grid A because there appears to be more paths available and also seems more obvious. However, there are in fact the same number of paths in each grid.

Another misconception identified by Kahneman and Tversky (1983) is the conjunction fallacy where the conjunction of two correlated events is judged to be more likely than either of the events themselves. In one study, they find that college students rated the probability of people that were 55 and had a heart scare higher than the probability of people that just had a heart scare. Kahneman and Tversky give a reason for this misconception. They believe that the two variables (age and incidents of heart scare) may be strongly linked to people's minds, albeit falsely. The college students might believe that age is a factor that could cause a heart scare or because most of the people they know who have had heart problems are older.

There are also many other misconceptions about probability mentioned in the literature such as equiprobability bias (e.g. Lecoutre, 1992; Fishbein and Schnarch, 1997; Canizares and Batanero, 1998) and 'compound approach' (Li and Pereira-Mendoza, 2002). Lecoutre (1992) describes the equiprobability bias as a tendency for people to look at random events as 'equiprobable' by nature and to judge outcomes as equally likely with equal probabilities. For example, in tossing two dice together, there is a tendency to erroneously evaluate the probabilities of getting a '6 and 6' as equivalent to getting a '6 and 5'. 'Compound approach' refers to the misconceived strategy students used in solving multi-stage chance comparison problems by splitting up the multi-stage experiment into several distinct experiments and then compounding the results for each stage intuitively without doing any calculations (Li and Pereira-Mendoza 2002). Li and Pereira-Mendoza mention an example where students are asked to draw one marble from each of two bags, each of which contains some black marbles and white marbles and the number of black marbles in each bag is greater than the number of white marbles. Li and Pereira-Mendoza hypothesise that students using this strategy would believe that drawing two black marbles at random from these two bags is the most likely outcome because drawing a black marble is more likely in each bag.

Rasfeld (2001) mentions a common fallacy where people think that the probability of an event which is highly improbable for themselves, is also improbable in general. He gives an interesting example quoted from the newspaper, Hanoversche Allgemeine Zeitung: '*These past few months thousands of American children have been writing letters to unknown US soldiers stationed in the Persian Gulf to show them that they have not been forgotten in their native country. Usually, the address is: "To any soldier". 27 year-old seargent Rory Lomas from Savannah, Georgia received such letter in Saudi Arabia. And by pure chance, 'the letter to any soldier' was written by Lomas's ten year old daughter*'. According to Rasfeld, many people see this event as fateful chance, extremely coincidence and unlikely. However, he argues that this is not the case and the probability of the event can be calculated to be about 0.63, which is quite high!

Misconceptions and difficulties concerning conditional probability have been written and reported by many statistics educators such as Falk (1987, 1989) and Borovcnik (1987). One of the most common misconceptions is the 'time axis fallacy' that relates to interpreting conditionality as causality (Falk, 1987). Various literature refers to this misconception as the 'Falk phenomenon' in honour of Ruma Falk, the prominent statistics educator who first mentioned it (Shaughnessy, 1992). Falk (1989) describes the intriguing problem that leads to the misconception as follows: '*An urn contains two white balls and two black balls. We blindly draw two balls, one after the other, without replacement. First, we ask about $P(W_{II}/W_I)$, ie what is the probability that the second ball is white given that the first is white? Students easily answer it correctly by 1/3. Second we ask about $P(W_I/W_{II})$*'. According to Falk, many students consider the second question as meaningless because they believe that conditioning the probability of an outcome of a draw on an event that occurs later is not allowed. Borovcnik (1987) argues that the students' belief is due to the missing causal influence that induces them to think that W_I is statistically independent of W_{II}. In Falk's experiment, some students give the answer as ½ and they base this solely on the composition of the urn at the beginning of the experiment and ignoring the information about the later outcome. Falk believes that students' refusal to consider evidence occurring later than the judged event reflects their causal reasoning in which she states: '*While the first causal inference is natural and compatible with the time axis, the second 'backward inference' seems to create a difficulty since it calls for probabilistic reasoning that is indifferent to temporal order*'. Other difficulties mentioned by Falk (1987) involve

a) the difficulty in determining the conditioning event
b) the confusion of the inverse, that is, lack of discrimination between the two directions of conditional probability, P(X/Y) and P(Y/X) and
c) the confusion students have about what they are given to work with due to the wording or framing of the conditional probability problem.

Garfield and Ahlgren (1988) mention several other general difficulties in learning probability. First, many students (at all levels) have an underlying difficulty with rational number concepts and proportional reasoning which are used in calculating, reporting and interpreting probabilities (see also Carpenter, Corbitt and Kepner, 1981). Second, many students faced difficulties in translating verbal problem statements which plague statistics as they do the rest of school mathematics (see also Hansen, McCann and Myers, 1985; Green, 1982; Bennie, 1998). Third, many students develop a distaste for probability through having been exposed to its study in a highly abstract and formal way. Garfield and Ahlgren (1988) summarise that inappropriate reasoning and misconceptions about statistical ideas are widespread and persistent, similar at all age levels and quite difficult to change even after teaching intervention.

3.8 Conclusions

For the teaching and learning of statistics to be successful, it is important that issues and problems pertaining to them are identified and tackled appropriately. For example, teachers already teaching statistics as part of the mathematics should have the opportunity to attend in-service courses to learn new ideas in teaching statistics. Student teachers in mathematics education courses should also be taught how to teach statistics effectively instead of treating the methods of teaching statistics the same way as with other topics in mathematics.

However, it should be helpful for teachers and student teachers to know about the principles of learning statistics as advocated by Garfield (1995):

- *Students learn by active involvement in learning activities.*
- *Students learn to do well only what they practise doing.*
- *Teachers should not underestimate the difficulty students have in understanding basic concepts of probability and statistics.*
- *Teachers often overestimate how well their students understand basic concepts.*
- *Learning is enhanced by having students become aware of and confront their misconceptions.*
- *Calculators and computers should be used to help students visualise and explore data, not just to follow algorithms to predetermined ends.*
- *Students learn better if they receive consistent and helpful feedback on their performance.*
- *Students learn to value what they know will be assessed.*
- *Use of the suggested methods of teaching will not ensure that all students will learn the material.*

Ovett and Reenhouse (2000) also present similar principles of learning statistics as above, derived from cognitive theory and supported by empirical results in cognitive psychology.

It is hopeful that by having these principles of learning statistics in mind, teachers can help improve students' attitudes towards learning statistics and prepare them to be statistically literate. It is also important for student teachers and teachers of statistics to familiarise themselves with learning models which would be helpful for the teaching and learning of statistics. In the next chapter, various learning models will be discussed in relation to the place of understanding learning in general.

CHAPTER FOUR

LEARNING FOR UNDERSTANDING

4.1 Introduction

The last chapter discussed some of the many factors affecting the students' learning of statistics. Learning in a course like statistics or for that matter any subject, is not a straightforward process. It involves much more than merely remembering what has been taught or read. Anecdotal evidence has revealed that students do not necessarily learn by having teachers/lecturers explaining to them how to solve a statistics problem (Garfield, 1995). Indeed, teachers/lecturers are often frustrated by the lack of understanding shown by the students even after showing them how to work out a problem and explaining all the steps clearly. This traditional method of teaching statistics where the teachers/lecturers describe definitions of the concepts and formulas to be learned, give a brief explanation and then proceed to show some computational examples is often viewed to be ineffective because it fails to establish a clear link between statistics and its uses in the real world (Yilmaz, 1996). Possibly, some kind of learning does take place but whether it is accompanied with understanding is another matter.

In this chapter, several issues related to learning for understanding in general are covered. Important questions like 'what is learning' and 'what is understanding' are discussed in detail. Students' approaches to learning are also deemed crucial in determining the outcomes of their learning. Three models of learning: Adult Learning Model, Ausubel's Meaningful Learning Model and Information Processing Models are also discussed. These three models are seen as relevant to the discussion about learning for understanding and also because this thesis is concerned with student teachers who are adult learners. These models of learning which describe how students learn or think also serve as a basis for models of instruction that draw conclusions about how teaching should be carried out (Romberg and Carpenter, 1986).

4.2 What Is Learning?

The question posed seems to be quite simple until one starts to think about it. All sorts of learning are going on all the time and they take place in many ways such as toddlers learning to walk, children at kindergarten learning their first alphabets and numbers, teenagers learning about life around them and senior citizens learning about how to operate computers. Learning can be intentional or unintentional (Slavin, 2000). When a student acquires information presented in the classroom or looks up something from the internet, he is said to have learned intentionally. On the other hand, a child's anxiety on visiting a dentist is arguably an unintentional learning behaviour because, from his past experience, he has learned to associate a visit to the dentist with pain.

Learning can easily take place by imitation. In imitation, a teacher demonstrates and the learner imitates and the quality of the learning is solely based in the faithfulness of the reproduction of the action which has been demonstrated (Atherton, 2003). In the traditional form of learning where imitation plays an important role, the 'inside' of the learner is treated as more or less empty and learning is understood as a process of getting the knowledge that is 'outside' the learner (the mind of the teacher) to move 'inside' (Shulman, 1999).

However, learning is not just the acquisition of content imitatingly or the transferring of knowledge from the teacher to the learner. A survey of the definitions of learning in standard psychology textbooks (e.g. Atkinson et al., 1993) and on the World Wide Web (e.g. www.prenhall.com/divisions/bp/app/armstrong/cw/glossary.html and users.wbs.warwick.ac.uk/dibb-simkin/student/glossary/ch04.html) tends to describe learning as a process by which relatively permanent changes occur in a person's behaviour caused by information and experience. Hamachek (1995) mentions that these changes in a person's behaviour do not solely refer to outcomes that are manifestly observable, but also to attitudes, feelings and intellectual processes that may not be so obvious. These changes should ideally enable the person to apply the new knowledge that has been acquired or use it to analyse new and unfamiliar situations. In addition, a desired learning outcome should be that a learner has the ability to exercise intellectual and creative powers, understand, judge, solve problems and communicate (Gibbs, 1992).

Are formal definitions of learning compatible with learners' conceptions of learning? Saljo (1979) carried out a study among a group of adult learners to find out what they understood by 'learning' and their replies fell into a hierarchy of categories as follows:

1. Learning as a quantitative increase in knowledge.
2. Learning as memorising.
3. Learning as acquiring facts, skills and methods that can be retained and used as necessary.
4. Learning as making sense or abstracting meaning which involves relating parts of the subject matter to each other and to the real world.
5. Learning as interpreting and understanding reality in a different way which involves comprehending the world by reinterpreting knowledge.

A sixth conception of learning which points to the process of 'changing as a person' is later added by Marton, Dall' Alba and Beatty (1993). The first three conceptions represents a more superficial view of learning where passive recall of content prevails while the subsequent conceptions interpret learning as an internal and active personal process in which the learner tries to understand reality and is therefore transformed by it (Saljo, 1979). Saljo describes the latter conceptions of learning (no. 4 and 5) as generative learning where the learner can apply the new knowledge gained to invent new strategies to solve new and novel problems.

Recent studies by Meyer (1998) and Bailey (2002) also agree with the categories of learning by Saljo. However, Meyer terms the first three conceptions of learning as 'accumulative' and the last two as 'transformative'. Another study by Entwistle (1997) reveals that about half of students entering higher education apparently believe that learning is demonstrated by reproducing the information provided by the teacher. In contrast, Entwistle points out that most lecturers expect students to abstract meaning from what is presented and later on do further readings and finally transforms the material acquired into an individual form of understanding. However, most students believe that by parroting the information given by the teachers/lecturers or in the case of mathematics and statistics, by following religiously the steps taken to work out a problem, they have shown some kind of understanding of what is being taught. Obviously, learning can lead to understanding but what actually is understanding?

4.3 What Is Understanding?

The acquisition of knowledge and skills has always been at the forefront of educational systems traditionally. Nevertheless, as Perkins (1993) points out, knowledge and skills in themselves do not guarantee understanding. Anybody can acquire knowledge and skills without understanding their basis or when to use them. For example, a student might know by heart all the facts and formulas in descriptive statistics and demonstrate routine skills to get the right solution to a problem and yet might display little or no understanding. Understanding is much more complicated than knowing. It is quite difficult to state categorically or to assess whether one understands something or not. Understanding is believed to be an internal state of mind, usually held to a degree rather than absolutely. Romberg (2000) points out that since learning occurs as a consequence of experiences, an individual can also understand complex ideas at a number of different levels in quite different ways.

According to Skemp (1976, 1987), the concept of 'understanding' is a *faux amis*. He looks at understanding mathematics from two perspectives, both of which fulfil particular functions in everyday life. They are *relational* understanding and *instrumental* understanding. The former refers to knowing both what to do and why while the later can be thought of as the ability to apply rules (knowing what to do) but without knowing the reasons (the why). Skemp (1976) further mentions that instrumental understanding is just a piece of rote memorisation of basic skills and algorithms while relational understanding is robust, connected and full of interconnecting ideas and less dependence on memory. The knowledge acquired by a learner instrumentally might be rendered useless if the learner confronts a slightly different problem situation while knowledge gains through relational understanding is more adaptable to new tasks. Skemp also suggests that:

> 'The kind of learning which leads to instrumental mathematics consists of the learning of an increasing number of fixed plans, by which pupils can find their way from particular starting points (the data) to required finishing points (the answers to the questions). The plan tells them what to do at each choice

> point...*what has to be done next is determined purely by the local situation...* There is no awareness of the overall relationship between successive stages, and the final goal... In contrast, learning relational mathematics consists of building up a conceptual structure (schema) from which its possessor can (in principle) produce an unlimited number of plans for getting from any starting point within his schema to any finishing point.'

Perkins (1993) and his colleagues at Harvard University formulate a conception of understanding based on the performance perspective. Briefly, this performance perspective mentions that understanding a topic of study is concerned with the ability to perform in a variety of thought-demanding ways relating to the topic such as to explain, gather evidence, find examples, generalise, apply concepts, analogise and represent in a new way. As an example, consider a student of statistics who knows about the concept of variation. He can explain what it means and knows the related measurements for it and their respective formulas. Also, he can describe some applications related to variation. Moreover, he can also relate the 'Law of Large Numbers' and the 'Central Limit Theorem' to variation. This shows that he has gained a good understanding of the variation concept according to Zeleke & Lee (2003). Perkins (1993) further stresses that the more thought-demanding performances the student can display, the more confident the teacher would be that the student understands.

Carpenter and Lehrer (1999) characterise understanding (in mathematics and science) in terms of mental activity that contributes to the development of understanding and not as a static attribute of a person's knowledge. The five forms of mental activity are as follows:

1. Constructing relationships – Learning with understanding involves making connections between students' existing knowledge and the new knowledge that they are learning as well as creating rich integrated knowledge structures.
2. Extending and applying mathematical and scientific knowledge – Learning with understanding is generative. Students can apply the knowledge to learn new topics and solve new and unfamiliar problems.
3. Reflection – To be reflective in their learning means that students look closely at the knowledge they are acquiring thoughtfully.

4. Articulation – This refers to the ability of a student to communicate his ideas and knowledge either verbally, in writing or graphically. Articulation also requires reflection so that critical elements can be identified and described.
5. Making knowledge one's own – In learning with understanding, an individual should construct knowledge through his own activity so that he can stamp his own mark in creating the knowledge.

Basically, the notions of understanding put forward by Skemp (relational understanding), Perkins (performance perspective) and Carpenter & Lehrer (five forms of mental activity) all point to the same thing; the main ingredient in understanding should be the ability of the learners to retain what they learn and transfer it meaningfully to novel situations.

What benefits are there for a learner to learn something and understand it properly? Hiebert and Carpenter (1992) list five consequences of understanding (as in mathematics):

1. Understanding is generative – By constructing his own knowledge, a learner can apply the new knowledge and invent new strategies to solve a variety of problems.
2. Understanding promotes remembering – Memory is a constructive or reconstructive process. It involves the same cognitive activity as understanding: constructing connections between representations of new knowledge and existing knowledge. If the connections are appropriate, understanding and memory are increased concurrently. (Issues about memory will be discussed in section 4.7)
3. Understanding reduces the amount that must be remembered – If something is understood, it is represented in a way that connects it to a network of mental representations. The more structured the network, the fewer individual pieces need to be retrieved separately. Memory for any single part of the network comes with memory for the network as a whole, reducing the number of items that must be remembered.
4. Understanding enhances transfer – Transfer is essential for mathematical competence because new problems need to be solved using previously learned strategies. It would be impossible to become competent if separate strategy would need to be learned for every problem.

5. Understanding influences beliefs – If a learner is asked to construct connections between pieces of information, the learner would then believe, for example, that mathematics is a cohesive body of knowledge such that information acquired in one setting will connect with information acquired in another. Such belief would in turn support the further growth of mathematical knowledge.

4.4 Approaches To Learning

Educators should be more concerned with the quality of learners' learning processes rather than the specific content or knowledge of the curriculum. In other words, it is better to know how the learners study than what they study. Ramsden (1992) has pointed out that by studying students' learning, educators could greatly improve their teaching. Over the years, students' approaches to learning have been a focus of study for many researchers (e.g. Marton and Saljo, 1976; Entwistle, 1987; Biggs, 1992; Ramsden, 1992; Marton and Saljo, 1997; Prosser and Trigwell, 1999). Garrison *et al.* (1995) mention that there is a general agreement that there are two fundamental approaches to learning: deep and surface; first identified by Marton and Saljo (1976). The qualitative features of the deep and surface approaches can be summarised below in Table 4.1:

Deep approach	Surface approach
Intention to understanding	Intention to reproduce
Vigorous interaction with content	Memorise information needed for assessments
Relate new ideas to previous knowledge	Failures to distinguish principles from examples
Relate concepts to everyday practice	Treat task as an external imposition
Relate evidence to conclusions	Focus on discrete elements without integration
Examine the logic of the argument	Unreflective about purpose or strategies

Table 4.1: Features of student approaches to learning Source: Entwistle (1987)

Students who have a limited view of learning (the first three categories in Saljo's conceptions of learning, 1976) are likely to adopt the surface approach while those who have the more sophisticated views tend to adopt the deep approach (Atherton, 2003). Gibbs (1994) argues that surface approach to learning almost invariably leads to poorer quality outcomes: show little understanding (instrumental), short term recall of the information and poor grades if the assessment favours deep approach. On the other hand, a deep approach can arguably lead to good understanding (relational), long term recall and better grades (see also Entwistle, Meyer and Tait, 1991). However, if the assessment procedures are mainly based on factual recall of knowledge and well-rehearsed algorithms, surface approach learners will be well rewarded.

It should be noted that the two approaches to learning are not personality traits or fixed characteristics but are mainly intentions (Biggs, 1999; Marton and Saljo, 1976; 1997). An individual may use both approaches at the same time although he may have a preference for one over the other depending on how the demands of each learning task is perceived (Ramsden, 1992). For example, if a student perceives the learning context to require a deep approach such as in problem solving, he will adopt the required approach. In contrast, if he perceives the learning context to demand regurgitation of factual knowledge, he will take the surface approach.

Saljo (1979) and Entwistle and Ramsden (1983) suggest another approach to learning. This is the strategic or achieving approach where the intention and motivation is to achieve the best possible grade through organised study strategies, effective time management and an alertness to the assessment methods. Atherton (2003) describes this approach as a very well-organised form of the surface approach. If one is a student attending a course with a heavy workload and a lot of assessments, one might be tempted to adopt a strategic approach.

4.5 Adult Learning Model

Are adult learners any different from young children and teenagers? Could the same methods and techniques used to teach children and teenagers be applied to adult? According to Malcolm Knowles, one of the pioneers in the field of adult education, the answers to the questions are yes and no respectively. Knowles's model of andragogy which he developed in 1970, attempts to describe how adults learn (1980). The term 'andragogy' is derived from the Greek words 'anere' which means adult and 'agogus' which means the art and science of helping students learn and was first coined by a German academician in 1833.

The main hypothesis in this model of andragogy is that adult learning should not follow the pedagogic model where the teachers assume the responsibility to direct learning: what will be learned, how it will be learned and when it will be learned (Knowles, 1980). Instead, adults should take control of their own learning. Adult learning should focus more on the process and less on the content. In general, Knowles characterises adult learners as being self-directed, goal oriented, relevancy-oriented, practical and have rich life experiences and knowledge.

Knowles *et al.* (1998) mention six assumptions of andragogy based on the characteristics of the adult learners. The assumptions are as follows:

- The learner's need to know – Adult learners need to know why they should learn something before undertaking to learn it. For example, in learning introductory statistics, student teachers need to know how statistical concepts and methods could help them in their future work as classroom teachers.
- The learner's self-concept – Adult learners need to be autonomous to direct themselves and take the responsibility for their own learning. In the learning process, teachers/lecturers should serve as facilitators to guide adult learners to their own knowledge rather than supplying them with facts and figures.
- The role of the learner's experience – Adult learners have accumulated a variety of experiences in life that may include previous education and work related activities. Thus, the heterogeneous nature of adult learners provides an opportunity to connect learning to their existing knowledge and experiences. Adult learners want to use what they know and relate them with the theories and concepts they are learning. However, it must be pointed out that these experiences and existing knowledge are sometimes imbued with bias and presupposition.
- The learner's readiness to learn – Adult learners are ready to learn something when they experience a need to learn it in order to cope effectively with real life situations. This is especially true with statistics since learners are often confronted with a variety of statistical information in their everyday life.
- The learner's orientation to learning – Adult learners tend to have task and problem-centred orientation in their learning and also need to know how what they are learning can be applied to their life. For example, the learning of statistics will be more effective if the teacher or lecturer uses real-life data and examples that adult learners may encounter in their life and on the job.

- The learner's motivation to learning – Adult learners have typically different motivation to learning than children or teenagers such as to make or maintain social relationships, to meet external expectations, learn to better serve others, personal advancement, escape/stimulation and pure cognitive interest (Cantor, 1992)

As mentioned earlier, the role of the teacher/lecturer in andragogy should just be confined to that of a facilitator. However, the relationship between the facilitator and the learner is deemed significant in andragogy to make the learning process a success. According to Pratt (1993), Knowles emphasised this point when he stressed the need to have a psychological climate of mutual respect, collaboration, trust, support, openness, authenticity, pleasure and humane treatment in the andragogy classroom.

The andragogy model has not been without critics. The main criticism is that the learner-centred approach proposed by andragogy relies on a great deal on the cognitive maturity of adult learners. According to Perry (cited in Lam, 1985), some of the adult learners are still operating a 'dualistic mode' and this group prefers a more structured learning environment. Pratt (1998) seems to agree when he argues that not all adults show the desired capability and readiness to exert control over instructional functions. Pratt (1993) also mentions about the tension between freedom and authority concerning the management and evaluation of learning.

Despite the criticisms mentioned above, it must be said that Knowles's model of andragogy has made a great contribution towards understanding how adult learners' learn. Curriculum planners in educational institutions that involve adult learners, such as teacher training colleges, must take into consideration that adult learners need to take control of their own learning and that the learning should be focussing more on the process rather than on the content. If applied correctly, the andragogical approach to learning can make a positive impact on the adult learner.

4.6 Ausubel's Meaningful Learning Model

David Ausubel is one of the pioneering cognitive educational psychologists and is also the first to put forward a model of learning which distinguishes meaningful learning from rote learning. In this model, Ausubel emphasises two important aspects (Novak, 1978):

- How individuals learn large amounts of information meaningfully from verbal/textual presentations in a formal setting.
- The significance of an individual's prior knowledge in influencing learning.

To highlight the significance of the two aspects, Ausubel (1968) famously claimed that ' *If I had to reduce all of educational psychology to just one principle, I would say this: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.*' He also stresses that those aspects are necessary for understanding to occur. He sees the function of prior knowledge as the provider of a bank of frameworks in the learner's mind which develops gradually into formal reasoning. The degree to which understanding can occur depends largely on the quality and the organisation of the learner's bank of frameworks. Some key ideas in Ausubel's learning model such as the two learning dimensions: rote-meaningful and receptive-discovery, subsumption and advance organisers will now be discussed in turn.

4.6.1 Rote And Meaningful Learning

Ausubel (1963) points out that meaningful and rote learning are not dichotomies but form two extremes of a continuum. There will be varying degrees of meaningful learning depending on the nature of the individual's prior knowledge and how it interacts with the new knowledge. However, the characteristics of these two types of learning can be summarised as in Table 4.2 below.

Meaningful learning	Rote learning
Non-arbitrary, non-verbatim, substantive incorporation of new knowledge into cognitive structure	Arbitrary, verbatim, non-substantive incorporation of new knowledge into cognitive structure
Deliberate effort to link new knowledge with high order concepts in cognitive structure	No effort to integrate new knowledge with existing concepts in cognitive structure
Learning related to experiences with events or objects	Learning not related to experience with events or objects
Affective commitment to relate new knowledge to prior learning	No affective commitment to relate new knowledge to prior learning

Table 4.2: Characteristics of meaningful and rote learning (Source: Hassard, 2000)

According to Ausubel and Robinson (1969), rote learning tends to occur when

- the material to be learned lacks logical meaningfulness
- the learner lacks the relevant ideas in his own cognitive structure
- the learner lacks the skills to enable him to learn meaningfully

Any of the above conditions alone would likely lead to rote learning. On the other hand, Ausubel and Robinson believe that meaningful learning could take place if the following criteria are met:

- the material to be learned must be related to some hypothetical cognitive structure consistently and substantively
- the learner must possess the relevant cognitive structures which relate to the material
- the learner must possess the intent to relate the relevant ideas to the new material nonarbitrarily and substantively

It must be pointed out that not all rote learning is bad or that everything can be learned meaningfully. For example, rote learning might be useful when learning a foreign language or calligraphic writings. Rote learning is closely associated with the surface learning approach while meaningful learning tends to correlate with the deep approach towards learning.

4.6.2 Reception And Discovery Learning

Ausubel and Robinson (1969) describe *reception learning* and *discovery learning* as the ways of presenting knowledge to the learners. According to Larochelle *et al.* (1998) reception learning is very much teacher-centred where the teacher acts as the primary source of information and knowledge, organises the learning material and presents it to the students in a relatively understandable form. The students are then required to internalise or incorporate the contents into their cognitive structures to learn and remember them.

In contrast to reception learning, discovery learning requires students to rearrange, organise and construct the links between the new information and their existing knowledge in order to discover the main content of the material to be learned. Bruner, who is a leading advocate of discovery learning, mentions that when students are motivated by their own curiosity to explore new things, the most meaningful learning can take place (Good and Brophy, 1990). Other advocates of discovery learning believe that it would lead to the acquisition of real knowledge and the knowledge can be retained much longer in the memory (Langford, 1989).

However, Ausubel (1968) points out that discovery learning is cumbersome and largely a waste of time although he does not deny its effectiveness in certain situations. Ausubel also claims that most people learn primarily through reception learning rather than discovery learning. Furthermore, he contends that those who condemn reception learning but stand behind discovery learning seem oblivious to the point that the method of learning does not determine the meaningfulness of the material learned. He argues that reception learning can be made meaningful if the material to be learned is presented conscientiously. In addition, Ausubel *et al.* (1978) states that both discovery and reception learning can be categorised to be either meaningful or rote learning depending on what happens after the material to be learned is presented to the learner (see Figure 4.1).

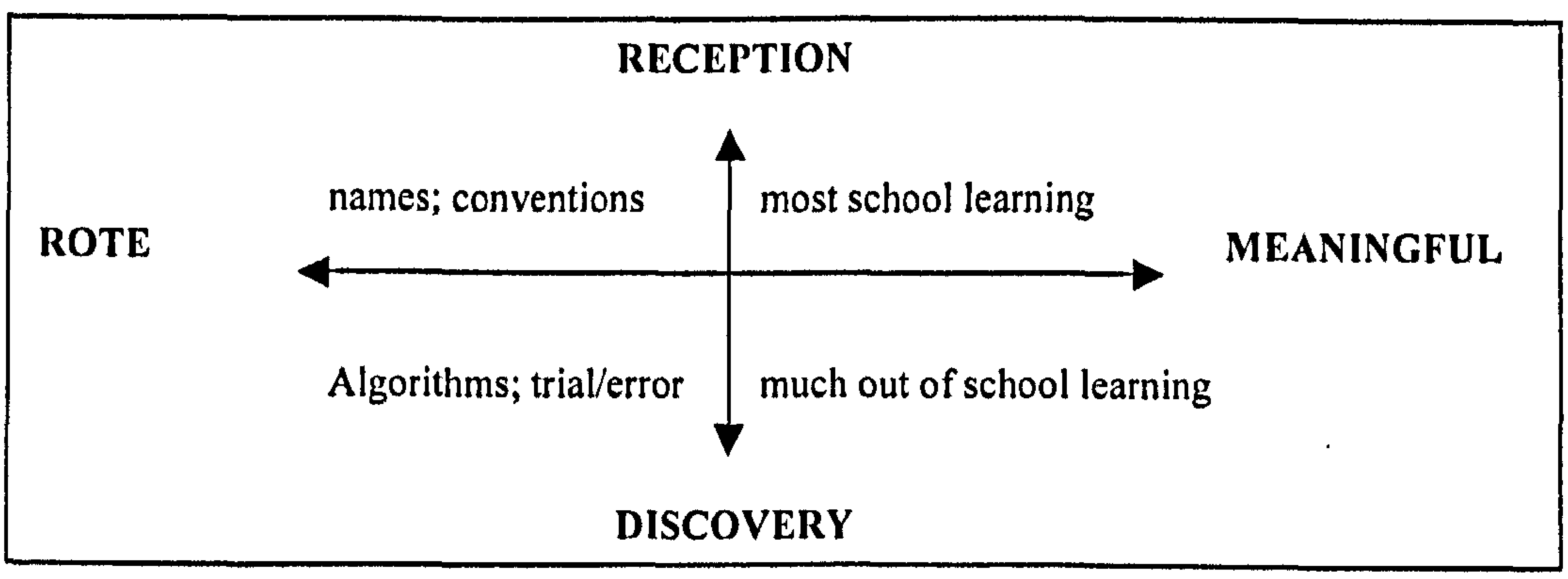


Figure 4.1: The Dimensions of Learning (Source: Ausubel et al., 1978)

4.6.3 Subsumption Theory

According to Ausubel (1968), to subsume is to incorporate new knowledge into a learner's cognitive structure. From his perspective, this is the meaning of learning. He contends that new learning does not result in new knowledge being added to existing relevant concepts. Instead, new knowledge interacts with and assimilates into these so-called anchoring concepts. Consequently, an altered form of both the new knowledge and the anchoring concepts emerges. Ausubel *et al.* (1978) labels the anchoring concepts as subsumers. He further adds that the process of subsumption is continuous and that its effectiveness depends on the growing differentiation and integration of the subsumers in the learner's cognitive structures. Thus, a learner whose subsumption process is well-developed, can be expected to solve more complex problems than a learner whose subsumption process is not that elaborated.

4.6.4 Advance Organisers

The advance organiser is another noteworthy idea that has been proposed by Ausubel to link effectively the new knowledge to be learned with the anchoring concepts in the learner's cognitive structure. It can also be described as a kind of conceptual bridge between the new material and the learner's current knowledge. Advance organisers are not merely previews of the new material to be learned but are more general and abstract concepts that will provide a great context to which the new knowledge can be subsumed and anchored (Ausubel, 1963). Ausubel proposes that advance organisers be used in the following two cases:

- When the learner does not possess the appropriate subsumers to relate to the new material.
- When the learner does possess the relevant subsumers but are not really developed such that they are not likely to be called upon to relate to the new material.

Since the function of an advance organiser is to facilitate meaningful learning, the advance organiser itself must be meaningful to the learner. Novak (1978) points out that it is unlikely for any type of advance organiser to function if the new material to be learned is itself a novelty and that relevant concepts are not in existence in the learner's cognitive structure.

Overall, Ausubel's theory is considered by educators to be sensible and consistent with what is going on in current educational practice. Learners are not empty pots to be filled and they come to the learning environment with existing knowledge that controls what they learn (Johnstone, 1987). Ausubel stresses that this existing knowledge is a prerequisite for the meaningful acquisition of knowledge to occur.

4.7 Information-Processing Model

To understand how an individual learns, it is important also to know how information is received and processed in the individual's mind. Human minds constantly receive information through the five senses: hearing, sight, smell, taste and touch. Some information is remembered for a short period and then forgotten while a tiny portion of the large amount of information received may stay in a human's memory for a very long time. However, it is believed that most information that enters a human mind is almost immediately discarded without even realising it (Slavin, 2000).

So, how and why does one's mind retain some information for a short while or even longer and totally reject some other information? Cognitive learning thinkers have addressed similar questions like this through the information processing model; the model of learning and memory that describes the process of encoding, storage and retrieval of information in the human mind. Basically, the approach to learning with this model is primarily through the study of memory. Research on human memory has contributed towards understanding of how information is remembered or forgotten (see for examples: Anderson, 1995; Ericsson and Kintsch, 1995). According to Brunning *et al.* (1995), memory is responsible for selecting what information enters the internal workings of the brain, what gets stored and what to retrieve.

There are several information-processing models which have been proposed but they are largely influenced by the work of Atkinson and Shiffrin in 1968 (see for examples, Sweller, 1988; Ashcraft, 1994; Brunning *et al.*, 1995). Bruning *et al.* (1995) propose a model, the 'modal model' (Figure 4.2) that contains common features of all the information-processing models at that time.

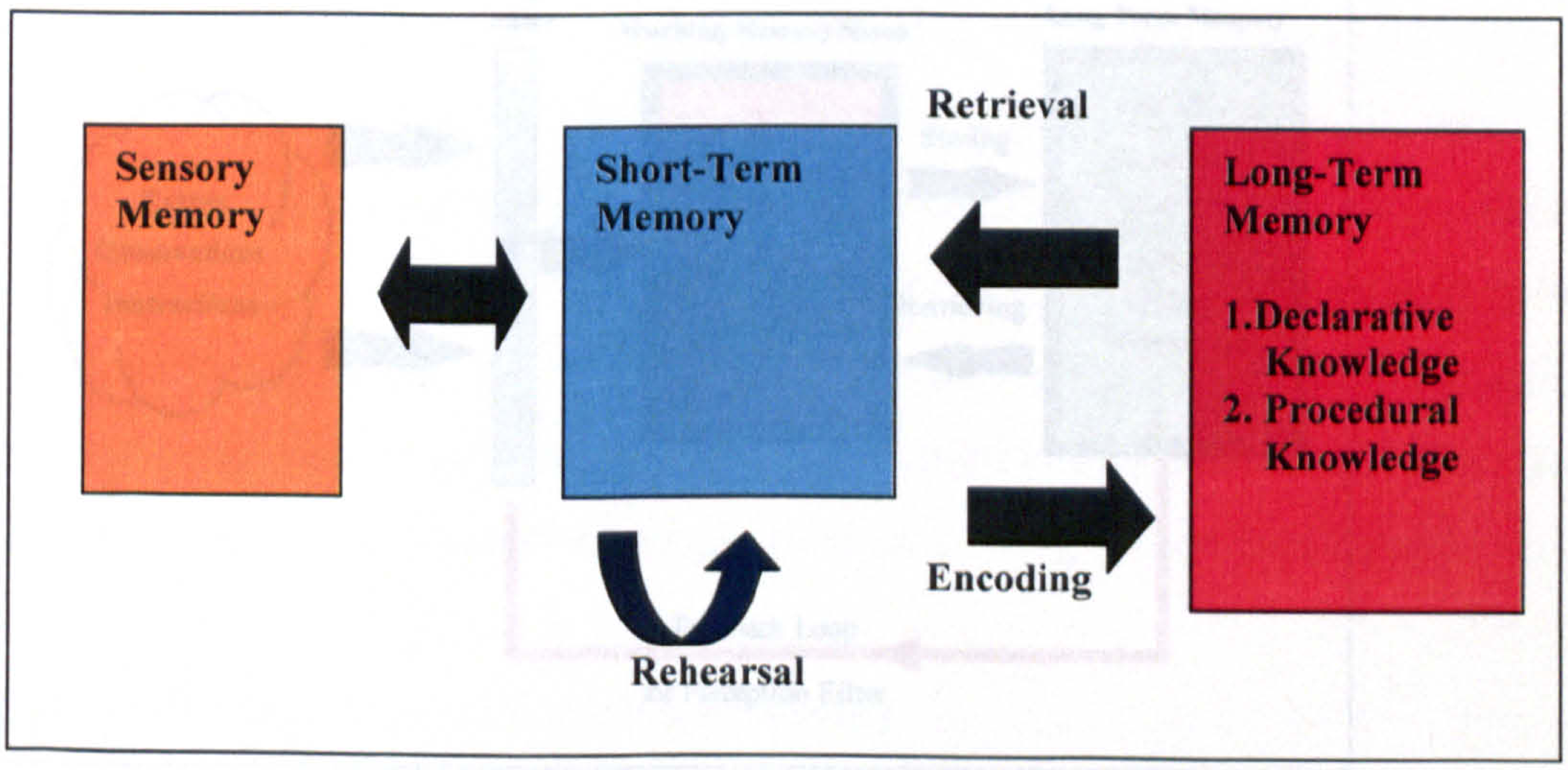


Figure 4.2 : The Modal Model **Source: Brunning *et al.* (1995)**

The modal model provides a useful organiser for discussion about memory. According to this model, the human memory system consists of three major components: sensory memory, short-term memory and long-term memory. During learning, information is processed through these three modes of memory. The information is first perceived by the sensory memory. On being recognised or attended to, the information is transmitted to short-term memory. If linkages are made between the new information and what is stored in long-term memory, then the new information is assimilated and accommodated into long-term memory and stored as cognitive structures or schemas.

Another useful information-processing model is the one developed by Johnstone (1993) (see Figure 4.3). The human memory system described in Johnstone's model is fundamentally the same as the one in modal model of memory. Johnstone's model can also be regarded as a model of learning which encompasses ideas from other learning models such as Piaget's stage theory, Ausubel's meaningful learning theory, Gagne's learning hierarchy and Pascual-Leone's neo-piagetian ideas (Bahar, 1999). An interesting feature of this model is that it makes predictions about how information is dealt with in the mind of the learner and also suggests explanation on difficulties in learning.

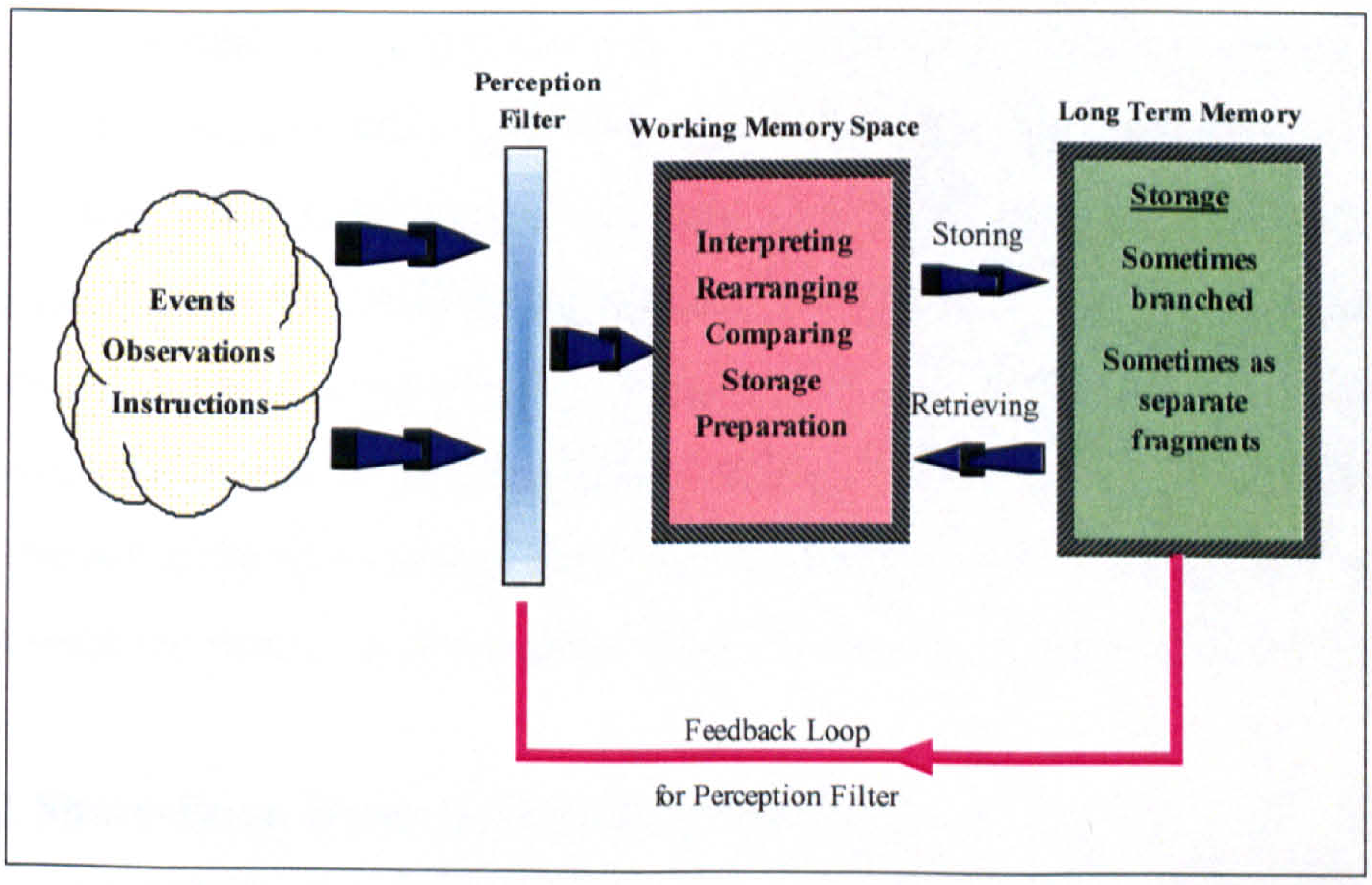


Figure 4.3: Johnstone's Information-Processing Model (1993)

The components of the human memory system in the information processing model will now be discussed in turn.

4.7.1 Sensory Memory (Perception Filter or Sensory Register)

Sensory memory is the first component of the human memory system that incoming information meets. It is also called by various other names such as sensory register (Atkinson and Shiffrin, 1968) and perception filter (Johnstone, 1991). The amount of information it receives is large and can hold on to the information for a very short time (Slavin, 2000). The information held is rapidly lost if nothing happens to it.

Sensory memory is considered to have a high and unlimited capacity that allows it to receive all sensory inputs in their original forms. It can be categorised into two distinct types: visual and auditory (Ashcraft, 1994; Brunning *et al.*, 1995; Kellong, 1995). The visual sensory memory which receives visual stimuli can hold the latter for about one second before it is encoded and absorbed into more lasting forms. The auditory sensory memory deals with sound related stimuli and can hold the latter for about four seconds after they disappear.

According to Brunning *et al.* (1995), the major function of the sensory memory is to select information that is perceived important to the learner. This selection process is referred to as perception. Perception is not a straightforward process because it involves mental interpretation and is influenced by many factors such as an individual's mental state, past experience and knowledge and motivation (Slavin, 2000). Johnstone (1993) holds the same view that the sensory memory acts as a perception filter that selects information. He points out that the perception filter is driven by the long-term memory since the former uses the prior knowledge, beliefs and attitudes stored in the long-term memory to assist in the mechanism of selecting and encoding the filtered information. The information is then passed on to the short-term memory where the subsequent stage of the processing system takes place.

4.7.2 Short-Term Memory (Working Memory)

Most researchers considered short-term memory to be the central part of the information processing model that people are conscious or aware of at any given time (Bourne *et al.*, 1986). It is the active part of memory in which a limited amount of information an individual has at any given moment are held and stored for a short time. It is believed that the short-term memory can hold information without rehearsal for no longer than 30 seconds (Slavin, 2000). Rehearsal by repetition is one way of prolonging the holding of information in the short-term memory. Once the individual stops thinking about a particular thing, it rapidly disappears from the short-term memory. These points are highlighted by Brunning *et al.* (1995) when they list two limitations of the short-term memory:

- Its delicateness which is symbolised by a rapid decay of the input whenever an individual's attention is diverted from what is to be remembered.
- Its limited capacity for storage

Studies by Miller (1956) have shown that short-term memory of an adult person to have a capacity of five to nine 'chunks' of information, or seven plus or minus two items, and this capacity varies among individuals. This means that any individual adult can only think of five to nine distinct things simultaneously. According to Miller, a 'chunk' is an arbitrary unit of information. When an individual is presented with a large set of elements (for example: numbers, letters or words) to remember, it is often helpful if he can combine the elements to form a smaller number of groups. Each of the groups is then referred to as a chunk of information. For example, it is common practice to combine the digits of a telephone number into a few chunks of several digits each rather than listing all digits in one long sequence. The mobile telephone number 07947421484 may be easier to remember in the form of 079-4742-1484 or 079-474-214-84 rather than the whole sequence. 079 is chosen as a chunk because it is the basic number of the service provider while the other chunks are chosen arbitrarily. The process of chunking is controlled by the individual based on his experience, knowledge and acquired skills (Johnstone and El-Banna, 1986). An individual cannot increase by practice the maximum number of chunks that can be held in the short-term memory but he can increase the amount of information units contained in each chunk (Bourne *et al.*, 1986).

The more contemporary term for short-term memory is working memory which has been widely used for the past three decades (for example Baddeley and Hitch, 1974; Johnstone, 1984; Ericsson and Kintsch, 1995). According to Slavin (2000), this term is more appropriate than short-term memory because it emphasises the part of the memory that is used to process information as well as holding it. Ashcraft (1994) points out that the short-term memory implies a static short-lived store which is limited in the amount of work that it can perform while working memory is more dynamic as a mental workplace for retrieval and use of the available information. Working memory is often referred to as an active system for temporarily storing and manipulating information needed in any range of cognitive tasks such as learning, reasoning and comprehension (Baddeley, 1986). According to Johnstone (1984), the manipulation of information in working memory involves working on it, organising it and shaping it before storing it in the long-term memory for further use.

Although short-term memory is usually regarded as synonymous with working memory, Johnstone (1984) provides a distinction between the two by giving the following example. If an individual tries to memorise a sequence of numbers, he may be able to recall it in the same order within seconds and without any processing taking place. Thus, the memory space is used completely as a short-term memory. If he is asked to perform some arithmetical operations on a set of numbers, obviously a working process has to take place and the memory space is now used as a working memory space. As mentioned earlier, the space of the working memory is limited and has the responsibility for holding and operating processes (Baddeley, 1994). Thus, it is likely that the working memory will be overburdened and overloading will occur. The effects of overloading in the working memory space will be discussed in 4.7.4.

The capacity of the working memory space of an individual can be measured by several methods. The most common measures are by using the traditional span tasks with digits or words (Oberauer *et al.*, 2003). Other measures involved using visual task such as Figural Intersection Test (Pascual-Leone, 1974). Although the approaches are different, the scores obtained by individuals from the digit span tasks and the Figural Intersection Test are highly correlated (Pascal-Leone, 1974; Su, 1991) In the digit span task, a series of digits (e.g. 9, 7, 4) is read aloud to participants who must immediately reproduce the series by writing down the digits into appropriate slots on the answer sheet. Participants are then given a new series of digits with an extra digit thrown in (e.g. 6, 9, 8, 6). This process may continue until the length of the series reaches up to nine digits. Research has shown that individuals may do well with six or seven digits but with eight or nine digits mistakes may start to creep in (Reisberg, 1997). When mistakes start to happen, it indicates that working memory space cannot hold that particular series of digits. Word span is identical to digit span except that words instead of digits are presented. Another version of the digit span task is the digit span backward task which is the task used for this thesis's research (for description of this task, please refer to section 6.2)

4.7.3 Long-Term Memory

Information may only be stored in long-term memory after being attended to and processed by working memory. Various descriptions of what long-term memory is have been made by many authors. Some examples are as follows:

1. The ultimate destination for information that one wants to learn and remember and also the place to store the information on a relatively permanent basis (Ashcraft, 1994).
2. A large store where facts are kept, concepts are developed and attitudes formed (Johnstone *et al.*, 1994).
3. A permanent repository of information that one accumulates over periods of days, weeks, months and years (Brunning *et al.*, 1995).
4. The immense body of knowledge and skills that one holds in a relatively permanent and accessible form (Cooper, 1998).

Most, if not all, of the definitions given above refer to the permanency of the memory because the authors believe that one never forgets the information held in the long-term memory. The only problem is that one may just lose the ability to find the information within his long-term memory (Slavin, 2000).

The main features of the long-term memory are that it has unlimited capacity for storing information and it is also everlasting (Solso, 1998). Information stored in long-term memory is not disposed to the same process of decaying characteristic as in the case of sensory memory and working memory.(Brunning *et a*l., 1995; Baddeley, 1994; Bourne *et al.*, 1986). Baddeley (1994) and Bourne *et al.* (1986) point out that some psychologists believe some information held in long-term memory might become inaccessible through time while others believe that metabolic changes in an individual could cause gradual decay to the information held.

According to Tulving (1993) and Squire *et al.* (1993), long-term memory consists of at least three components: episodic, semantic and procedural. Episodic memory is concerned with the recollection of experienced events and episodes that an individual might have such as a conversation one had with the boss yesterday or the death of a colleague five years ago. Semantic or declarative memory contains the facts and the vast network of conceptual information underlying an individual's general knowledge which also includes problem solving skills and learning strategies (Slavin, 2000). Semantic memory is naturally expressed as 'remembering that' or 'knowing of what' (Solso, 1998). Meanwhile, procedural memory refers to 'knowing how' to perform certain activities like how to write, how to ride a motorbike and how to play chess. Some of the procedural memory such as walking and talking may be activated automatically without the need for high levels of conscious attention as shown from a study conducted by Maxwell *et al.* (2003).

Slavin (2000) points out the differences between the episodic, semantic and procedural memory in terms of how information is stored and organised:

- Information in episodic memory is stored in the form of images that are organised on the basis of when and where events happened
- Information in semantic memory is organised in the form of networks of ideas.
- Information in procedural memory is stored as a complex of stimlus-response pairings.

Information stored in and retrieved from the long-term memory plays a crucial role in selecting what goes through the perception filter and in aiding working memory to process new information (Johnstone, 1993). Oberauer *et al.* (2003) liken the storage and retrieval processes to that of a library's card-cataloguing system. The human memory system seems to know whether an item of information has been stored or not and can retrieve and recognise any particular item by using strategies such as pattern recognition, rehearsal and effective organisation.

4.7.4 What Happens When Working Memory Is Overloaded?

As mentioned earlier in 4.7.2, the number of items or 'chunks' that can be held simultaneously by a person in the working memory or short-term memory is limited to about 'seven plus or minus two' and that this varies among individuals. A learner may be able to handle a learning task confidently when it is equal to or less than his measured working memory capacity. What happens when the learning task is beyond the working memory capacity of the learner? An overloading may occur unless the task is rearranged into manageable and effective chunks.

According to Barber (1988), the working memory can easily be overloaded if the information one is concerned with exceeds the upper limit of his working memory space. Johnstone (1997) agrees with Barber's statement when he presents the following dilemma: '*if there is too much to hold, there is not enough space for processing; if a lot of processing is required, it cannot hold much*'. Working memory can be easily overloaded when faced with an onslaught of irrelevant information, unfamiliar terms, novel concepts and difficult formulas. For example, Johnstone and Wham (1982) demonstrate that students' working memory space tends to overload during practical work in science because of the many tasks they have to tackle at the same time. They argue that the overloading of the working memory occurs when the students fail to differentiate between the unnecessary information (noise) and the essential information (signal). To overcome this, they suggest that the 'signal' should be given prominence by highlighting what is preliminary, peripheral and preparatory in order to suppress the 'noise'.

In higher education where lecturing is the traditional style of teaching, Johnstone (1999) suggests that overloading can happen during lectures because the students try to squeeze in everything into their limited working memory space. This includes taking down notes either from the board or from the lecturer's spoken words to trying to make sense of what they are writing down and then trying to understand them.

Overloading of the working memory can also occur in examinations, especially in a conceptual subject like mathematics which may lead to brief and incomplete answers. Johnstone (1988) points out that an overloading may make further demands on an examination candidate by requiring him to break down a question into sub-goals and chunk information and then into usable units for use in working memory. He also mentions the redundant noise in the working memory such as the superfluous information or context which can drown out the signal. For a candidate with a small working memory capacity, the irrelevant information can only worsen his performance.

Learning in a language other than one's mother tongue can also contribute towards overloading. This has been found by Selepeng (1995) who conducted a study among school children in Botswana where the medium of instruction is English rather than the children's native language. Selepeng found that the process of translating one language to another in a learning situation may use up about a chunk of the working memory space. According to Johnstone (1991), even one unfamiliar word or a common word in an unfamiliar context can consume valuable working space. For example, in statistics, words such as 'certain', 'at least', 'unlikely' and 'impossible' can cause confusion when apply to probability and thus can contribute towards overloading to the working memory.

4.7.5 Working Memory and Achievement

The relationships between working memory and variables such as examinations, psychometric tests, problem solving tasks and cognitive styles of learning have been investigated by many researchers over the years. Johnstone and El-Banna (1986) studied the effects of working memory on students' problem solving performance in chemistry and they found a significant correlation between the two variables. They also discovered that if the number of things needed to solve a chemistry problem exceeds the students' working memory capacity then their performance will catastrophically deteriorate. Other similar studies by Opdenacker *et al.* (1990) with undergraduate medical students solving chemistry problems, Johnstone *et al.* (1993) and Chen (2004) with students solving physics problems and Geary and Widaman (1992) with secondary students solving mathematics problems also arrive at the same conclusion.

Working memory capacity is also found to have significant effects on student performance in conventional school and university examinations (Johnstone & El-Banna, 1986). In a study about intelligence in Spain and Brazil involving high school students and university undergraduates, Colom *et al.* (2003) find a high correlation between working memory capacity and measures of intelligence. It seems that people who perform well in tests of intelligence tend to have high working memory capacity, enabling them to perform complex cognitive operations such as inductive and deductive reasoning as well as abstraction. The relationship between working memory and cognitive style of learning has also been a focus in many research studies and this relationship will be discussed in Chapter Five.

4.8 Conclusions

Learning for understanding can be achieved if teachers/lecturers make the efforts to find out what their students' conceptions of learning are and what constitutes understanding. Learning for understanding should enable the learners to retain what they learn and apply the new acquired knowledge to analyse new and unfamiliar situations. Therefore, educators must pay more attention to the quality of students' learning processes rather than emphasising the transmission of knowledge. Students should also be guided towards approaching learning deeply and not superficially. By adopting the deep approach to learning, it is hoped that students can learn meaningfully and gain better understanding of what they are learning.

The learning models discussed in this chapter point out the fact that learners restructure the new information or knowledge to fit into their own cognitive frameworks rather than merely receiving the material as it is given. In this way, the learners actively and individually construct their own knowledge and this contributes to develop understanding of what they are learning. Learning with understanding can help to overcome the problem of overloading to the working memory as well as to promote remembering.

In looking at how students learn through the various learning theories, it is also essential to know about their cognitive styles of learning because researchers have long recognised the unique differences among individuals and the impact these differences can have on students' learning. This will be looked into in the next chapter along with learning and teaching strategies that can lead to learning for understanding.

CHAPTER FIVE

FIELD DEPENDENCE/INDEPENDENCE COGNITIVE STYLE OF LEARNING AND TEACHING STRATEGIES

5.1 Introduction

It is a fact of life that individuals differ in many ways. Thus, it would not be surprising if individuals as learners differed in the way they learn too. There are several factors that affect learning such as age, aptitude, intelligence, learner characteristics and teaching strategies employed by educators. The last two factors are of great importance because of the significant effects they have on the learning processes (Vincent & Rossi, 2001). A review of the literature on the numerous research studies carried out in the area of learner characteristics has shown that cognitive styles of learning have an impact on academic achievement and intellectual development. In an ideal situation, there is also suggestion that teaching strategies should be matched to learner characteristics in order to achieve a maximum effect of the teaching and learning processes. However, in reality, this is impossible to implement due to many factors, which may be organisational and practical.

In this chapter, cognitive styles of learning will be discussed and attention is given to the field dependence/independence construct since in this research study, it is the cognitive style that was being looked into. A review of research studies carried out in the area concerning field dependence/field independence construct will be presented. The two teaching strategies that will be discussed in this chapter are lecturing and cooperative learning.

5.2 What are Cognitive Styles?

The unique psychological differences among individuals and their significance in learning have long been recognised by educators and researchers alike. Every individual has his own way of collecting and organising information depending on his cognitive structure and what he already knows. The manner in which an individual collects and organises the information into beneficial knowledge tends to show a consistent pattern (Cross, 1976). The tendency displayed by the individual consistently to adopt a particular type of information strategy is referred to as his cognitive style. Thus, according to Riding & Rayner (1999), '*cognitive style is seen as an individual's preferred and habitual approach to organising and representing information*'. Other earlier definitions of cognitive styles also illustrate variations in individual information processing such as

a) 'modes by which learners approach, acquire and process information and include the consistent ways in which an individual memorises and retrieves information' (Witkin & Goodenough, 1981)
b) 'an individual's characteristic and consistent approach to organising and processing information' (Tennant, 1988)
c) 'characteristics modes of perceiving, remembering, thinking, problem solving, decision making that are reflective of information processing regularities that develop in congenial ways' (Messick, 1993)

There are three main attributes of cognitive style which are as follows:

- Bipolar – This attribute of bipolarity with regard to level makes the dimensions of cognitive style value neutral, that is there is no issue of good or bad since each pole has its adaptive value in different contexts (Witkin & Goodenough, 1981; Green, 1985).
- Consistent across domains – Cognitive styles are thought to be relatively stable ways of how an individual approaches a learning task across a range of different domains (Kahtz & Kling, 1999). As suggested by Witkin & Goodenough (1981), cognitive styles are ways of moving towards goals rather than goal attainment. As such, they are independent of the subject content.
- Stable over time – Many researchers such as Green (1985) and Witkin & Gooodenough (1981) believe that the stability of cognitive styles runs over years rather weeks or months. However, they point out that cognitive styles are not totally unchangeable.

It should be pointed out that the concept of 'cognitive styles' is different from 'cognitive abilities'. The latter are usually thought to be more domain specific and are rather about subject-content mastery while the former are usually consistent across domains as mentioned above. Some other differences between cognitive style and ability, as suggested by many researchers (cited in Alamolhodaei, 1996), are given in Table 5.1.

Cognitive style	Ability
The manner of moving towards a goal	Competence in goal attainment
Measured by the degree of some manner of performance	Measured in terms of level of performance
Refer to the way in which behaviour occurs and the question of how	Refer to the content or the question of what
Bipolar dimensions	Unipolar dimension
Value neutral	Values are significant.

Table 5.1: Differences between cognitive style and ability.

Therefore, as we can see from the table above, cognitive styles are relatively independent of abilities. Nevertheless, having more of an ability is usually considered beneficial while having a particular cognitive style simply denotes a tendency to act in a certain way (Harmon, 1984).

A number of cognitive styles have been identified and studied over the years. These include variables within a single dichotomy such as field dependent/field independent, global-holistic/focused-detailed, reflection/impulsivity, right-brained/left-brained and convergent/divergent. Among these variables, the field dependence/field independence (FDI) dimension has emerged as one of the most widely studied cognitive styles with the broadest application to the problems of education (e.g. Messick, 1976; Witkin & Goodenough, 1981; Green, 1985; Tinajero & Paramo, 1997).

5.3 Field Dependence and Field Independence (FDI)

According to Tinajero & Paramo (1998), the construct of field dependency originated from the 1940's 'New Look' movement's members who were concerned that traditional models of perception did not really take into account an individual's unique aptitudes, needs and personality. Some of them, like Witkin and his colleagues, conducted studies to determine the contribution of visual and postural cues to perception of the vertical (Witkin *et al.*, 1977; Witkin & Goodenough, 1981). They found that most of the individuals displayed a consistent pattern in the usage of only one or another type of cue. Some individuals appeared to use the cues of the visual field while others tended to rely on postural (i.e., kinaesthetic, tactile and vestibular) cues. The former were designated 'field-dependent' while the latter were designated 'field-independent'.

After several more studies, the construct of field dependency was broadened from the perception of the vertical to include perceptual and intellectual problem solving (Witkin *et. al.*, 1977). Field independent people (who rely on an internal frame of reference) are found to be more capable at cognitive restructuring and disembedding skills than field dependent people (who rely on an external frame of reference). According to Riding & Cheema (1991), these skills provide a structure for an ambiguous stimulus complex, break up an organised field into its basic elements and provide a different organisation to a field than that which is suggested by the inherent structure of the stimulus complex. In simpler terms, Johnstone (1991) describes a field independent person as the one who can easily discern 'signal' (relevant materials) from 'noise' (incidental and peripheral materials) while a field dependent person exhibits difficulty in distinguishing the 'signal' from the 'noise'.

Witkin and Goodenough (1981) describe several research studies that showed significant relationships between field dependency and personality differences such as interpersonal relations and social interaction. Thus, Witkin postulated that field dependency reflects a broad dimension of self/non-self segregation manifested by perception of the vertical, cognitive restructuring abilities and social functioning (Goodenough, 1986). To explain the interrelationship of the various dimensions within the construct of field dependency, Witkin developed the psychological differentiation theory (Witkin, 1974). This theory describes the differentiation process as one of the creation of inner boundaries between the inner core of the self and the environment. It also suggests that a more differentiated individual shows more self/non-self segregation. The more segregated the self, the more likely the individual is to be field independent and vice-versa.

It should be noted that there are a few factors like age, gender and socio-economic status that affect the degree to which an individual is either field dependent or field independent (Musser, 1998). According to Musser, children are generally field dependent. As they develop into adulthood, their field independence increases. In general, adult learners are found to be more field independent. Regarding gender, Musser reports that many studies showed that males always achieved better scores in field dependency tests. However, he points out that these differences in scores are so small and thus the effect of gender on field dependency is insignificant (see also Riding *et al.*, 1995). Socio-economic status may also affect field dependency. In a study by Forns-Santacana *et al.* (1993) in Spain, the researchers found significant differences in the test scores to determine the degree of field dependency among students of different socio-economic classes. Students from lower socio-economic class are found to be more field dependent than their peers from the higher socio-economic background.

Other factors that affect field dependency are childhood upbringing and hemispheric lateralisation (Musser, 1998). Musser mentions some early studies by Witkin on childhood upbringing which indicated that a child is likely to be relatively field dependent when obedience to parental authority and external control of impulses are strongly emphasised. However, when a child is encouraged to develop separate and autonomous functioning, he or she will tend to be relatively field independent. Studies by Pizzamiglio (1974) and Silverman *et al.* (1966) revealed that there are actual differences in the hemispheric lateralisation between field dependent and field independent individuals because the right and left hemispheres of the brain function independently. Therefore, left-handed individuals are found to be more field dependent than right-handed individuals.

The notion that the construct of field dependency is a cognitive style is not unanimously agreed. Grigerenko & Sternberg (1995) have argued that the construct is, at least in part, a measurement of ability which they describe as a combination of intellectual skills and strategies. Thus, they conclude that the field dependency construct may in fact be an indicator of ability or intelligence rather than style. This conclusion is also supported by Richardson (2000) who noted the frequent higher associations between the field dependency construct and spatial as well as overall intelligence. On the other hand, Tinajero & Paramo (1998) present evidence from many researchers who concluded that the field dependency construct is independent of ability or intelligence.

5.3.1 Measurement of field dependency levels

Originally, Witkin and colleagues used the body adjustment test (BAT) and then the rod and frame test (RFT) to determine an individual's level of field dependency. In the BAT, a volunteer would sit on a chair that could be tilted in a tiny room (more like a big box) that was tilted either to the left or to the right. The volunteer would then be asked to adjust the tilt of the chair to the upright position. The way he oriented himself (either to the tilt of the room or to the true upright position) would then be noted. In the RFT, a volunteer would sit in a dark room and view a tilted illuminated square with a luminous rod suspended within the frame. The volunteer would then be asked to move the tilted rod to the upright position within the tilted frame. The way he defined the upright (either using the frame or using his body) would then be recorded. Based on the findings from these tests, Witkin hypothesised that individuals were either dependent on the contextual surrounding or independent of the external field for their perception of the upright (Witkin *et al.*, 1977).

Later, Witkin developed the Embedded Figures Test (EFT) and Group Embedded Figures Test (GEFT). The latter can be administered to several persons simultaneously while the former is an individually administered test. These widely used instruments measure an individual's ability to recognise and identify a simple shape from a complex visual field and thus to restructure information as a correlated skill (Witkin *et al.*, 1977). This process of recognising and identifying, over a range of given visual fields, enabled the measurement of field-dependence/field-independence. The more shapes correctly recognised and identified by an individual, the better he is at this disembedding process and is therefore said to be field independent. The converse is true about field dependent individuals.

According to Witkin *et al.* (1977), the degrees of field-dependence or field-independence can be defined as a continuum with field dependent at one end and field independent at the other end. In the middle of the continuum is the category 'field-mixed' or 'field-neutral (Liu & Reed, 1994; Dyer, 1995) or 'field-intermediate' (Bahar and Hansell, 2000) which does not have a clear orientation. It must be pointed out that being strongly field independent or field dependent is neither good nor bad and that scores on the GEFT form a normal distribution (Witkin *et al.* 1971).

A host of researchers have evaluated the validity, reliability and the usage of GEFT and came out with the conclusion that this instrument appears to have 'desirable measurement characteristics' of the field dependence/independence cognitive style (e.g. Thompson and Melancon, 1987). GEFT has also underpinned most of the research effort and reported outcomes in the construct of field dependence/independence cognitive style for the past thirty years. It is also easy to use and adaptable to large groups.

5.3.2 Characteristics of Field Dependent/Independent Individuals

The main difference between field dependent and independent learners is in cognitive restructuring: the ability to distinguish the parts of an image or visual environment from the whole or field and then ordering or applying structure to those parts (Witkin *et al.*, 1977; Riding & Cheema, 1991). Field dependent individuals are easily distracted from the intended message of the image or field by the visually striking or salient, but irrelevant, information (Witkin *et al.*, 1977; Whyte *et al.*, 1996). They lack the inherent ability to impose order and defer to organisational structure represented by the visual field. In contrast, field independent individuals are not distracted by irrelevant details and are able to extract pertinent parts from an image or environment. They also have less difficulty in imposing organisation in an unstructured environment since they apply internally generated structural rules from previous experiences or developed from cues readily available (Witkin *et al.*, 1977; Riding & Cheema, 1991; Davis, 1991).

There are various attributes found in the literature to describe field dependent and field independent individuals. Field dependent individuals are sometimes described as global, not usually perceptive, externally referential, passive learners, non-verbal, group-oriented, sensitive to social interactions and criticisms and extrinsically motivated (Riding & Cheema, 1991; Liu & Reed, 1994; Lyons-Lawrence, 1994). Some of the attributes used to describe field independent individuals are analytical, visually perceptive, internally referent, active learners, individualistic and intrinsically motivated (Lyons-Lawrence, 1994; Reiff, 1996). In their reviews of the field dependency literature, Garger and Guild (1987) summarise the characteristics of field dependent and field independent learners. This summary is presented in the Table 5.2.

Field Dependent	Field Independent
a. Perceives and approaches things globally	a. Perceives and approaches things analytically
b. Experiences in global fashion and adheres to structures as given	b. Experiences in an articulate fashion and imposes structures of restrictions
c. Makes broad general distinctions among concepts and sees relationships	c. Makes specific concept distinctions and little overlap
d. Social orientation. Tend to be influenced by peers	d. Impersonal orientation. Less likely to seek peer input
e. Learns material with social content best	e. Learns social material only if have to
f. Attends best to material relevant to own experience	f. Interested in new concepts for their own sake
g. Requires externally defined goals and reinforcements	g. Has self-defined goals and reinforcements
h. Needs organisation provided	h. Can self-structure situations
i. More affected by criticisms	i. Less affected by criticisms
j. Uses spectator approach for concept attainment. Attend to salient cues first, regardless of relevancy	j. Uses hypothesis-testing approach to attain concepts. Sample more cues, regardless of saliency
k. Extrinsically motivated	k. Intrinsically motivated

Table 5.2: Differences between the characteristics of field dependent/independent learners. Source: Garger & Guild (1987)

Due to the differences between the two styles, it is important for educators to take into account this factor when contemplating classroom strategies so as to accommodate both groups. Educators should remember that field dependent learners prefer a slower pace of stimulus presentation and move more slowly through materials than field independent learners (Davis, 1991). Witkin *et al.* (1977) suggest that field dependent and field independent learners may produce the same performance when learning materials are well structured and organised. Zehavi (1995) seems to agree with the suggestion when he found that there was no significant difference in performance between the two groups in junior high school level mathematics using highly structured computer-based instruction.

5.3.3 Field Dependency and Academic Achievement

Witkin *et al.* (1977) mention that many research studies have revealed that there is no difference in learning ability between field dependent and field independent learners. However, the learners may respond differently to the learning environment and how the content of the curriculum is being presented. As such, it might be reasonable to expect that these differences might affect the ways in which the learners perform in the classroom. Nevertheless, early studies by Witkin and colleagues found that there was no link between field dependence-independence and overall academic achievement (Tinajero & Paramo, 1998). This was in tune with Witkin's hypothesis of neutrality concerning the construct of field dependency (Witkin *et al.*, 1977). This hypothesis contends that field-dependent and field-independent subjects are equally well-adapted to meet demands of their environment.

According to Tinajero & Paramo (1998), Witkin's early finding was disputed by many researchers such as Dubois & Cohen (1970) who found that examination marks obtained by psychology students at an American university were significantly correlated with both tests of field dependence-independence (Rod and Frame Test and Group Embedded Figures Test). An extensive study by Griffin & Franklin (1996) also showed that field independence predicts success at the undergraduate level across many disciplines. In his study, Davis (1991) reports about field independent learners outperforming field dependent learners across all levels of schooling with current forms of instruction and assessment. Reiff (1996) argues that typical instructional environments favour field independent learners since the desired schooling outcomes closely match to that of the learners' characteristics. Terrell (2002) records that his research study revealed a significant relationship between field independence and the membership in America's Middle and High School Programmes for the Academically Gifted.

In their review about the relationship between field dependence-independence and achievement at school, Tinajero & Paramo (1998) conclude that, in general, field independent learners perform better than their field dependent counterparts in almost all the areas which have attracted the most attention: language, mathematics, natural sciences and social sciences. Among these four areas, Tinajero & Paramo considered mathematics to be a subject of particular interest since mathematics is seen as an activity requiring a high level of disembedding and restructuring ability.

Tinajero & Paramo note many studies (e.g. Frank in 1986 and Roszkowski & Snelbecker in 1987) which consistently reported a superior performance in standardised mathematics tests among field independent individuals as compared to field dependent individuals across a wide range of ages. In a study exploring the relationship between field type and mathematics ability, Zehavi (1995) also found that there was a significant correlation between the two variables with field independent students displaying better mathematics skills and ability. Tinajero & Paramo also mention other studies (e.g. Roberge & Flexer in 1985 and van Blerkom in 1988) which revealed that the superiority of the field independent individuals over the field dependent individuals in those mathematics tests is maintained when the effects of intelligence are ignored or controlled. Nevertheless, Tinajero & Paramo do not mention what kind of strategies the researchers used to separate the variability due to intelligence. Perhaps, the researchers used randomly designed experiments or statistical methods such as the analysis of covariance (ANCOVA) to control the effects of intelligence in determining the relationship between the degree of field dependency and the mathematics tests.

Field independence is also found to be significantly correlated with higher mathematics achievement especially for concepts and applications (e.g. Vaidya & Chansky, 1980; Alamolhodaei, 1996). In solving mathematical problems, field dependent individuals are observed to perform worse than field independent individuals (e.g Van Berkom, 1988 (cited in Tinajero & Paramo, 1998); Christou, 2001). Garet (cited in Tinajero & Paramo (1998)) believes that the difficulties the former have for resolving mathematical problems are due to the demand for restructuring figurative or symbolic material which is frequently present in problems. Less tangible variables such as anxiety are also thought to be involved in the differences in mathematics performance associated with field dependency (Tinajero & Paramo, 1998). A study by Hadfield & Madux (cited in Tinajero & Paramo, 1998) reveals that field dependence is significantly correlated with mathematics anxiety and that the greater anxiety of field dependent individuals may be an obstacle to achievement.

According to Tinajero & Paramo (1998), almost all the studies carried out, whether of achievement in specific disciplines or across the board, gave strong evidence of a relationship between field dependence/independence and overall academic achievement at school/college (see also for example Witkin *et al.*, 1977; El-Banna, 1987; Al-Naeme, 1988; Ziane, 1990; Alamolhodaei, 1996; Uz-Zaman, 1996; Danili, 2001; Christou, 2001). However, Tinajero & Paramo point out that some studies have shown that there is no significant correlation between field dependence/independence and achievement but '*in no case have field-dependent subjects been shown to perform better than field-independent subjects*'.

Since almost all the studies mentioned above pointed to the superiority of the field independent individuals over their field dependent counterparts in overall academic achievement, perhaps the field independent traits should be taught and nurtured to individuals when they are still young. However, up until now, there is still no evidence that this can be done.

5.3.4 Field Dependency and Memory

Messick (1993) has suggested that cognitive characteristics of field dependency are related to the memory system of the information processing model. The relationships are described below:

- attentional processes in the sensory memory – field independent individuals are able to separate, attend to and use all relevant cues while field dependent individuals have difficulty attending to and using non-salient cues.
- the encoding of information in working memory or short-term memory – field independent individuals have the ability to reorganise and encode information efficiently while field dependent individuals do them inefficiently.
- the organisation and retrieval processes in long-term memory – field independent individuals can provide structure and have richer semantic links while field dependent individuals simply accept the available structure and have fewer links and isolated storage of information.

Tinajero & Paramo (1998) note several research studies (e.g. Berger & Goldberger in 1979 and Goodenough in 1976) that hypothesised the effects of the observed differences in some information processing components had on how students perform in the classroom. Field independent learners are thought to be more effective in their learning than the field dependent learners due to their memory efficiency (Davis & Frank, 1979; Emmett *et al.*, 2003). Lange (1995) points out that learners who have difficulties with selective attention in sensory memory are likely to have less efficient short-term memory processes such as encoding and less effective long-term retrievals especially when cognitive load is high. High cognitive loads would result in superficial and incomplete processing of information with only the most salient and intense features being encoded. This in turn would provide only a few and/or incorrect links to existing knowledge and thus would inhibit the storage and retrieval processes.

Witkin & Goodenough (1981) claim that field independent individuals are more likely than field dependent individuals to provide organisation for ambiguous information and to restructure information. They argue that the latter have better disembedding and cognitive restructuring abilities that leads to more efficient processing in working memory and better storage in long-term memory. Studies done by Spiro & Tirre (1980), Strawitz (1984) and Durso, Reardon & Jolly (1985) all showed that memory differences among field dependent and field independent individuals do exist in some long-term memory storage, organisational and retrieval processes. Field independent individuals are more likely to use previous information during recall and are more adept at discriminating between internally and externally generated memory traces.

Studies carried out by a number of researchers have found that learners who are field independent and with high working memory capacity tend to produce the best performances in academic achievement (e.g. El-Banna, 1987; Al-Naeme, 1988; Ziane, 1990; Christou, 2001). It is also found that there are differences in performance among learners with the same working memory capacity but with different levels of field dependency (El-Banna, 1987; Al-Naeme, 1988; Danili, 2001; Christou, 2001). Performance would decline when a learner is more field dependent. Field dependent learners need more working memory space to compensate for their field dependence characteristics. Also, it is found that there is little variation in performance between high working memory capacity but field dependent learners and low working memory capacity but field independent learners. According to Johnstone *et al.* (1993), the former could not benefit from their larger working memory capacity because it is rendered less efficient due to the presence of irrelevant information. On the other hand, the latter could maximise the usage of their limited working memory space since only the relevant signal would be received and processed.

5.3.5 Implications of Field Dependence/ Field Independence for Teaching and Learning

The previous sections have discussed issues such as characteristics of the field dependent and field independent individuals who are learners and also the academic achievement of the respective groups. In light of this, questions such as 'what is the best strategy to teach these two group of learners?' and 'is it better to match teaching to the learner's cognitive style or force him to adapt to whatever teaching strategies that are imposed in the classroom?' should be raised. Chinien & Boutin (1993) review the literature on field dependency and argue that this cognitive style should be given top priority when designing teaching and learning strategies in the classroom. They also argue that by ignoring the cognitive style of learners, teaching/learning materials and contexts will be biased.

At tertiary level, lecturing is often seen as the most efficient way to disseminate information to a large number of students. In a study on the effect of field dependence and independence on learning from lectures, Frank (1984) presents evidence that field independent students outperform field dependent students. Frank suggests that this is due to the more efficient note taking during lectures by the former. The latter's performance is consistent with the characterisation of field dependent learners as having difficulty abstracting and organising information that is presented as part of a larger organised field. Perhaps a teaching strategy which involve group-oriented and cooperative work situations should be introduced since it is better suited to help field dependent students to excel in their learning. This is because field dependent students have strong interpersonal orientation and greater sensitivity to social stimulation (Witkin & Goodenough, 1981). These two teaching strategies: lecture and co-operative learning will be discussed in sections 5.4 and 5.5.

Teachers' cognitive styles should also be taken into consideration as many studies had shown that teachers of different cognitive styles approached teaching differently (Witkin *et al.*, 1977; Riding & Rayner, 1999). Gargle & Guild (1987) summarise the characteristics of field dependent and field independent teachers as described below.

- Field dependent teachers prefer teaching situations such as student-centred activities that allow interaction and discussion with students. Field independent teachers prefer impersonal teaching situations such as lectures and they emphasise cognitive aspects of instruction.
- Field dependent teachers use questions to check on students' learning following instruction but provide less feedback and avoid negative evaluation. Field independent teachers use questions to introduce topics and following students' answers by giving corrective feedback. They also do not mind using negative evaluation.
- Field dependent teachers are strong in establishing warm and personal learning environments while field independent teachers are strong in organising and guiding students in their learning.

Thus, would students of a particular field type be better off being taught by teachers of similar field type or is it better to mix them? Several studies carried out over the years have suggested that the matching of students' and teachers' cognitive styles could have positive effects on the teaching and learning behaviours (Witkin *et al.*, 1977). Witkin *et al.* suggest that teachers tend to do better with students with the same cognitive style. Similarly, students tend to respond better to the teaching styles of the teachers who have the same cognitive style as them.

However, a study by Strawitz (1984) revealed that the matching of students to that of the teachers' cognitive style might not necessarily produce the best achievement in students. They found that field independent students achieved equally well with either field independent or field dependent teachers. On the other hand, field dependent students performed better with field independent teachers than with field dependent teacher.

In reality, it is quite difficult to match learners of one field type to teachers of similar field type. Nevertheless, teachers regardless of their cognitive styles, should be trained to broaden their teaching styles to suit the range of cognitive styles within the students they teach. According to Riding & Rayner (1999), this has the potential to result in improved teaching since the teaching methods adopted will appeal to a wider range of students. For example, Bertini (1986) points out that field dependent students who are likely to avoid mathematics should be taught mathematics by different methods and approaches adapted to their degree of field dependency. In lectures, Frank (1984) suggests that lecturers could help improve field dependent students' performance through a combination of training in note taking skills and the provision of organisational structure like lecture outlines.

5.4 Lecturing

Lecturing is a common teaching strategy at tertiary level especially involving large classes. Lecturing is defined as the formal presentation of content by the educator as a subject matter expert for the subsequent learning and recall in examinations by students (e.g. Vella, 1992; Ruyle, 1995). Although the usefulness of other teaching strategies such as cooperative learning is being extensively examined, the lecture method is still the popular choice among educators at institutions of higher learning. Some of them may argue that it is the traditional form of teaching at tertiary level and, therefore, is expected by students and lecturers alike (Swanson & Torraco, 1995).

Students and lecturers often have the same mental image of how the lecture method works: the lecturer, as a figure in authority, talks and writes something on the board and the students listen and take copious notes of what is written on the board (Middendorf & Kalish, 1996). Lectures are generally presented from the lecturer's perspectives and the emphasis is on facts and skills and not on the relationships between them, especially in quantitative courses like mathematics and statistics. McIntosh (1996) points out that lecturing is frequently a one-way verbal communication unaccompanied by discussion, questioning or immediate practice. Students' need for interaction with the lecturer is not given due consideration or is assumed to be unimportant.

5.4.1 Strengths of the Lecture Method

Lecturing still has its rightful place in higher education because it has a number of strengths as a teaching strategy. One of its major strength is the ability to convey large amounts of core knowledge in a short time and without interruption (Soliman, 1999). It is also efficient for large audiences and allows for materials scattered over a wide variety of resources to be uniquely summarised (Lesky, 2002). Thus, the lecturer can identify clearly what material is relevant and can model how one reasons through a topic. Lectures are particularly useful for students who are having problems with their reading or who have difficulty organising facts they have just read in a sensible way.

Cashin and Downey (1990) mentions that some students value mass lectures because each listener has access to the same information, the lecturer exercises maximum control over the class and the lecture method poses minimum threat to students since they are not required to do anything but listen. These students prefer a lecture to be a relatively passive activity. Lecturers of large classes often resort to a lecture format because it is easier and safer to implement in the belief that there is less that can go wrong when doing a lecture if one is to compare with other teaching strategies that are more student-centred (Magel, 1998).

5.4.2 Weaknesses of the Lecture Method

According to Bonwell & Eison (1991), many studies have suggested that the exclusive use of the lecture in the classroom constrains student learning. The most noted weakness of the lecture method is that it is seen as inadvertently encouraging student passivity (Chism *et al.*, 1990). Students, especially in large classes expect that they will not be actively involved in learning and their role is just to sit back, relax, listen and copy down some notes. According to Trigwell & Prosser (1996), this passivity can hinder learning and consequently diminishing students' interest and leading in most cases to students adopting a surface learning approach (see section 4.4). The lectures also encourage one-way communication and thus lack feedback to both lecturer and the student concerning the latter's learning.

Another major weakness of the lecture method is the inability of most students to listen effectively and attentively over a sustained period (Chism *et al.*, 1990; Bonwell & Eison, 1991). For example, Meyers and Jones (1993) reported these statistics regarding lectures in an introductory psychology course:

- Students retain 70 % of the information in the first ten minutes of a lecture but only 20 % in the last ten minutes.
- Students are not attentive to what is being delivered in a lecture 40 % of the time.
- Students who took the course knew only 8 % more than those who had never taken the course.

These statistics revealed that lectures tend to be forgotten quickly and the lecturers' desire to cover the syllabus and rush through things may prove to be a waste of time.

In the lecture method, students are assumed to have good note-taking skills but studies have shown that many students face difficulty in taking down notes especially when the lecture contents are conveyed verbally (e.g Johnstone & Su, 1994; Bonwell & Eison, 1991). In his study, Su (1991) discovered that students with high working memory capacity are better note takers than students with low working memory capacity. Su also found that there is not much difference between field dependent and field independent students in taking down notes that appear on the board but a marked difference is detected between the two groups when the lecture contents are conveyed orally (see also Franks, 1984).

Another assumption about the lecture method is that all students learn at the same pace and the same level of understanding (Johnson *et. al.*, 1992). This is obviously not true. Research has indicated that students have different cognitive styles and different levels of understanding when it comes to learning (see section 5.3.2 and chapter 4). Thus, it is necessary that alternative teaching strategies that promote active learning should be interwoven with the lecture method

5.5 Cooperative Learning

Research and anecdotal evidence strongly support the claim that students learn best when they actively participate in their learning (e.g. Bonwell & Eison, 1991). This active learning strategy involves '*providing opportunities for students to meaningfully talk and listen, write, read, and reflect on the content, ideas, issues, and concerns of an academic subjec*t' (Meyers & Jones, 1993). Instead of traditional lectures where teachers disseminate information to students for them to remember, teachers should be encouraged to introduce active learning activities where students would be able to construct their own knowledge. A form of active learning favoured by many educators who are concerned about improving education regardless of discipline or level of instruction is the cooperative learning strategy (e.g. NCTM, 1991; Johnson & Johnson, 1994; Garfield, 1993; Felder & Brent, 2001).

Cooperative learning is defined as the instructional use of small groups in which students work together to maximise their own and each other's learning in solving problems, completing tasks and accomplishing common goals (Johnson & Johnson 1999). Thus, each member of the group is responsible not only for learning what is taught but also for encouraging and supporting other group members to learn and, consequently, creating an atmosphere of achievement.

There are several types of groups in cooperative learning including formal and informal groups (Johnson *et al.*, 1991). Informal groups might consist of 'turn to your neighbour' discussions and are often used to supplement lectures in large classes. Formal groups consist of the same students who work together for a longer period of time. Students in each group may be assigned specific roles which can be rotated each time the group meets. These roles may help students to get started on the activity and also prevent one student from doing all the work. Johnson & Johnson (1994) suggest that the number of members in each group depends on the complexity of the learning tasks given. However, they report that the highest levels of success occur when the size of the groups is kept small. As a matter of fact, they favour groups of two for many cooperative tasks.

It should be pointed out what is not cooperative learning. According to Johnson & Johnson (1994), the following scenarios are not cooperative learning:

- Having students sit side by side at the same table and talk with each other as they do their own work
- Having students to do a task individually with instructions that whoever finishes earlier should help the other members of the group
- A group of students has been assigned to do a report but only one student does all the work and others go along for a free ride

The teacher should realise that '*...putting students into groups does not necessarily gain a cooperative relationship, it has to be structured and managed by the teacher...*' (Johnson & Johnson, 1994). In cooperative learning, the role of the teacher is that of a facilitator rather than as an expert dispensing knowledge (Cooper *et al.*, 1991). The facilitator may allow students to form the groups themselves or the groups may be formed by the facilitator to be either homogeneous or heterogeneous

(Garfield, 1993). While the groups in the cooperative learning class work on their tasks, the facilitator will move from group to group, observe the interactions between group members and will intervene if necessary. This will provide the facilitator with an ongoing and informal assessment of how well students are learning and understanding the course material.

5.5.1 Elements of Cooperative Learning

It must be stressed that cooperative learning is not a synonym for students working in groups. According to Johnson & Johnson (1994), an instruction strategy only qualifies as cooperative learning under certain conditions that include the following elements:

- Positive interdependence – Every student has the twin responsibilies of learning the assigned material himself and ensuring that all group members learn it as well so as to achieve a common goal. Students must believe that they 'sink or swim together' and 'all for one and one for all'. Each group member's contributions and efforts are required and indispensable for group success. If any group members fail to deliver, everyone suffers as a result.
- Face-to face promotive interaction – This can be characterised by students providing each other with feedback and effective assistance in order to improve their subsequent performance, challenging each other's conclusions and reasoning in order to promote higher quality decision making and greater insight into the problems being considered, and last but not least, teaching and encouraging each other.
- Individual accountability – Each student is held accountable for individual learning. When the performance of individual students is assessed, the results are made known to the individual and the group. The student is held responsible by other group members for contributing his fair share of the work towards the group's success. Individual accountability is the key to ensure that each member of the group turns out to be a stronger individual in his own right after learning cooperatively.
- Use of interpersonal and small-group skills – Students must be taught adequate collaborative social skills if cooperative learning is to be productive. To achieve common goals, students must get to know and trust each other, communicate accurately and unambiguously, accept and support each other and resolve conflict constructively.
- Group processing – This may be defined as reflecting on a group session to describe what actions by the group members were helpful and unhelpful, and subsequently make decisions about what actions to change or continue. Through this process, it is

hoped that the effectiveness of the members in contributing to the joint efforts to achieve the group's goals can be clarified and improved.

All the elements mentioned above must be given due attention by teachers in order for cooperative learning to be successful. To summarise, cooperative learning should involve small heterogeneous groups working together towards a group task in which each member is individually held accountable for part of an outcome that cannot be completed unless group members are positively interdependent. Members should also engage in team building activities and other tasks that deal with the social skills needed for effective teamwork. Lastly, members should also engage in group processing and evaluation activities where they discuss the interpersonal skills that influence their effectiveness in working collaboratively.

5.5.2 Why Use Cooperative Learning?

Working together in a small group to get a job done, like in cooperative learning, has the potential to benefit students in many ways. Small group learning activities often result in peer teaching where students teach each other especially when a group member understand the material better or learn more quickly than others (Garfield, 1993). Research has shown that having students teach each other often leads to their own improved understanding of the learning material (e.g. McKeachie *et. al.*, 1986; Johnson *et. al.*, 1998; Felder *et al.*, 1998, Haller *et.al.*, 2000). It seems that teaching each other '*...allows students to cognitively rehearse and relate course material into existing schema or conceptual frameworks, thus producing a deeper, contextualised level of understanding of content*' (Cooper & Robinson, 1998).

Student interaction makes cooperative learning meaningful. During discussions, members are given the opportunity to demonstrate their knowledge of what they have learned as well as allowing for clarification, questions and expressions of opinion (Tinzmann *et. al.*, 1990). Members, especially the reserved individuals, are likely to be less inhibited to ask questions and to contribute to the discussions in small groups. For example, in a statistics class, members discuss their approaches to solving a statistics problem, explain their reasoning and defend their work Thus, this encourages the comparison of ways of understanding the problem, problem solving strategies and different solutions to the problem. According to Garfield (1993), this allows students to learn first-hand that there is not just one correct way to solve most statistics problems. Consequently, students engaged in interaction often exceed what they can achieve by working independently (Tinzmann et. al., 1990).

Learning by means of small group activities also increases students' motivation because they feel more positive about completing a task successfully working with others than by working individually (e.g. Johnson *et. al.*, 1991; Nichols & Miller, 1994). By working together towards a common goal, group members may develop positive feeling and show greater commitment towards the group and may result in building up considerable camaraderie. This increase in motivation may also lead to improved students' attitudes towards a subject or a course. Studies carried out by many researchers in various disciplines have reported about students' positive attitudes toward cooperative learning (e.g. Schultz, 1989; Nichols & Miller, 1994; Giraud, 1997; Magel, 1998; Felder & Brent, 2001).

Without a doubt, cooperative learning has long been advocated as a teaching strategy because of its effect on academic achievement. After more than fifty years of research and a multitude of studies, researchers strongly concur that cooperative learning represents a valuable strategy for helping students achieve high academic standards across all levels and disciplines (Kagan, 1993; Cohen, 1994). In a review of studies dealing with the impact of cooperative learning in science, mathematics, engineering and technical classes at tertiary level, Springer *et al.* (cited in Cooper & Robinson, 1998) report that students exposed to small group instruction produced better achievement in several types of tests and assessments than students taught in more traditional methods like lectures.

The success of implementing cooperative learning strategies in teaching statistics (especially introductory statistics courses at tertiary level) has also been reported by many statistics educators such as Steinhorst & Keeler (1995). Giraud (1997), Rinaman (1998), Magel (1998) and Gunawardena (2002). Their studies support the hypothesis that cooperative learning in statistics class results in students obtaining higher achievement than students in lecture instruction. Findings also suggest that cooperative learning promotes retention of learning material for most students as evidenced by differences in statistics examination scores The studies also reveal that cooperative learning is especially beneficial for students who are least prepared for statistics since the strategy helps them to learn statistics without anxiety.

5.5.3 What Are the Problems in Implementing Cooperative Learning?

At tertiary level, the main obstacles to implement cooperative learning are the desire of the lecturers to get through the syllabus, and dealing with large classes (Felder & Brent, 1999; 1996). Lecturers invariably express concern that they have to present a lot of material in their courses and they believe that by spending time in class on cooperative learning activities, they will never cover the prescribed syllabus. Nevertheless, Felder & Brent (1996) point out that much of what happens in most traditional classes featuring lectures is a waste of time because students do nothing else but copy down the lecturer's notes.

In large classes, Felder & Brent (1996) report that lecturers are wary of using small group activities for two reasons: '*they worry that some students will refuse to participate under any circumstances and that the noise level during the activity will make it difficult to regain control of the class*'. According to Garfield (1993), students who are used to sitting in lectures and prefer to be passive learners might resist teaching strategy that appears difficult and challenging. Some students may prefer to work alone and may hate the idea of working in a group. Garfield suggests that this may be related to the issue of grading fairness. Some students are concerned that giving one grade to the whole group irrespective of the students' contribution to the group, might seem unfair. To alleviate this concern, a grading policy where the amount of individual member contributions is given weight, should be adopted. To address the second problem, the lecturer should establish some simple rules for students to follow. For example, to bring students' attention back to the lecturer, it is important to establish a signal, such as a handclap, for them to cease the group activities (Felder & Brent, 1999).

Another reason some lecturers may react negatively to use cooperative learning is the uncomfortable feeling about relegating their dominant role to the background (Garfield, 1993). These lecturers are used to performing in front of appreciative students, elegantly demonstrating how to solve a difficult problem or showing proofs to a theorem. With cooperative learning, they merely observe, listen and assist students only as needed.

5.6 Conclusions

The discussions of the field dependence and independence construct have revealed many fascinating things and the most important of all is the implication of this cognitive learning style has for education. The learners' behaviour, ability to organise information, need for assistance and guidance, performance in examinations and ability to comprehend assignments are all affected by the field dependence and independence construct. Although Witkin *et al.* (1971) have pointed out that being field dependent or field independent is neither good nor bad, one cannot help but notice how much field independent learners are favoured in education in this body of research.

The discussions on the teaching strategies have shown that the lecture method does not generally provide an active learning environment for students. Even if all the characteristics of a good lecture are present, studies have indicated that the traditional lectures are essentially a poor means of producing quality and effective learning On the other hand, the cooperative learning method ensures student involvement by drawing them into the learning process and helps students make the transition from passive listeners to active participants in their own learning.

It has been suggested that there should be a match between the learner characteristics and the teaching strategy used by the educator. If there is a mismatch, students tend not to perform well. At tertiary level, the traditional lecture method is thought to disadvantage field dependent students because it is seen as an unstructured and impersonal method of teaching. Although it is quite difficult and not practical to create different teaching strategies to accommodate different kinds of learner, educators in higher learning institutions should use a flexible variety of strategies to help all students learn.

In addition to the usual lectures, educators can help students engage in their learning by providing visual aids (charts and diagrams), written outlines or study guides of key points, structured opportunities for group interaction, practical real life examples and a variety of assignment formats (Montgomery & Groat, 2002; Vincent & Ross, 2001).

CHAPTER SIX

EXPLORATORY STUDY: THE FIRST EXPERIMENT

6.1 Introduction

In the previous chapters, issues are raised about how some psychological factors affect the outcomes of students' learning. Research carried out over the years revealed that factors like the size of the working memory space and the degree of field dependency do influence learners' performances in learning and in assessments (see for example: Berger, 1977; El-Banna, 1987; Al-Naeme, 1991; Bahar & Hansell, 2000). However, most of the research studies carried out in this area were focussed on adolescent learners at secondary and early tertiary levels. Therefore, it was the initial aim of this first experiment to establish a baseline as to what extent the psychological factors mentioned above affect student teachers' learning of statistics. It is acknowledged that student teachers, being adult learners, are quite different from other learners because they are seen as more mature and they bring along with them a wealth of experiences into the classrooms. It is also interesting to see what kind of attitudes student teachers have toward learning statistics and the impact it has on their learning.

In this chapter, the methodology used in this study is discussed. Firstly, the sample and the instruments used in this experiment are described in detail. Then, a brief summary of the research questions in this study is given. Finally, the results and analyses as well as the discussions of the findings from the study instruments are presented.

6.2 The Study Sample

The study sample consisted of almost the whole population of student teachers (aged between 19 and 45) who were enrolled in the introductory statistics course offered by the Faculty of Science and Technology, Sultan Idris Education University in Malaysia. The student teachers came from a variety of educational backgrounds. Some were experienced former teachers (non-graduates but with teaching certificates) while others came straight out from schools (with Malaysian High School Certificate which is equivalent to GCE 'A' Level or Scottish 'Higher Grade') or colleges (graduated with diplomas in various fields).

The breakdown of the student teachers participating in this study according to programmes and gender is shown in Table 6.1 below:

	Male	Female	Total
Mathematics Education (ME)	39	144	183
Science Education (SE)	3	25	28
Information Technology Education (ITE)	23	55	78
Others (from other faculties)	0	6	6
Total	65	230	295

Table 6.1: The breakdown of student teachers participating in the study

Altogether, there were three classes involved in this study with about 100 student teachers in each class. A single lecturer taught all the classes assisted by a tutor who helped out with the tutorials. The lecture method was the teaching strategy employed by the lecturer where facts and figures as well as some examples were read out from the transparencies on the overhead projector or written down on the white board. In the tutorial classes, the tutor helped the students with the problem sheets given by the lecturer

This exploratory study was carried out in December 2001 during the fourth and fifth weeks of the new semester (2001/2002) which began in November 2001. At that time, only the first four topics in the introductory statistics syllabus had been covered (see Appendix A). Permission was sought from the lecturer to conduct the study and two hours (one hour each week) were spent with each class to collect the data.

6.3 The Study Instruments

To establish the baseline study for this thesis, the following assessment tasks were used:

1. Questionnaires – To assess student teachers' attitudes toward learning statistics and their opinions on the introductory statistics course.
2. The digit span task – To measure working memory space capacity.

3. The Hidden Figure Test – To measure the degree of field dependency.
4. Structural Communication Grids – To assess student teachers' basic knowledge and understanding of descriptive statistics and probability.

All the study instruments were in the Malay Language. The final overall marks for the introductory statistics course were also obtained from the lecturer who taught the course and then compared with some of the above assessment tasks to see whether there might be relationships between them. The overall marks consisted of scores from class quizzes, mid-term test and final examination. These assessments were time-based and merely testing student teachers' factual knowledge and their ability to substitute figures into a formula and to compute an arithmetically correct answer. The final semester examination question paper can be found in Appendix B.

6.3.1 Validity and reliability of the study instruments

Before proceeding to describe each of the instruments in turn, perhaps it would be worthwhile to touch on the ideas of validity and reliability in research measurement. These two qualities are deemed to be the most important characteristics of a research instrument whether in the form of a test, an interview, an observation or a questionnaire (Ary *et al.*, 2001). Validity refers to the extent to which an instrument measures what it is intended to measure. However, one can never be completely sure of having achieved validity of any form in research (Reid, 2003). Nonetheless, steps must be taken to ensure the validity of the instrument. In order to ascertain this, some kind of criterion external to the instrument used is needed which may involve relying on the views of experts (face validity) or some completely separate evidence (concurrent validity).

Reliability refers to the extent to which an instrument is consistent in measuring whatever it is purported to measure. Reliability is the tendency of the instrument to produce similar scores or values when applied to the same individuals and under the same conditions but at a different time. It is possible for an instrument to be reliable without being valid, but it cannot be valid if it is not also reliable! (Ary *et al.*, 2001). Methods to estimate the reliability of an instrument are either based on correlational procedures (e.g. test-retest, split-half) or on the proportion of respondents who get the items right or wrong (e.g. Kuder-Richardson Formula 20 and 21 and Cronbach

Alpha). Most of the methods (apart from test-retest) merely give indication about internal consistency of an instrument whether: items in that instrument only measure the same thing. However, if the items are designed to measure many different things, then consistency across items is therefore meaningless (Reid, 2003). As pointed out by Reid, many test and questionnaires have items that are designed deliberately not to measure the same thing. If one were to estimate the reliability of a test that measure many things using any of the methods described above, the reliability coefficient obtained would probably be quite low. Nevertheless, if the tests or questionnaires are designed carefully to avoid ambiguity, the items are moderately difficult and the length of the tests/questionnaires is reasonable, then reliability will not be a major issue

6.3.2 Questionnaire

A questionnaire was used to survey student teachers' attitudes and perceptions toward learning statistics in this study. The questionnaire is one of the most appropriate and useful data gathering instrument to survey opinions and attitudes (Fraenkel & Wallen, 2000). A questionnaire that is properly designed can provide precise insights into how students think and the way they evaluate situations and experiences (Reid, 2003). It is also very efficient in terms of researcher time and effort because a researcher can obtain data from hundreds if not thousands of respondents in a relatively short time (Robson, 1994).

In designing the questionnaire for this study, ideas were taken from some instruments measuring attitudes toward statistics (e.g. Schau *et al.*, 1995; Green, 1993) to ensure validity. In addition, face validity was also sought by sending a translated version of the questionnaire (in Malay Language) to two lecturers in Malaysia to seek their opinions and suggestions. They also helped to pilot the questionnaire with their own students (methodology course in mathematics education) to detect ambiguities and sources of confusion.

The questionnaire given to the participants in this study contained items that covered the following areas: personal information, attitudes toward learning statistics, opinions about the introductory statistics course, participant's preference between learning statistics and some other enrolled courses; and some open-ended items on what statistics is about, the importance of statistics, opinions about the statistics course and topics in introductory statistics that participants found easy or difficult (see Figure 6.1).

To assess the participants' attitudes, opinions and preferences, one or other of the following two approaches was used. The first approach was the Likert method that used a five-point scale where participants responded to various statements using 'strongly agree', 'agree', 'neutral', 'disagree' and 'strongly disagree'. The other approach used was the semantic differential method based on the work of Osgood *et al.* (1957). This approach is concerned with assessing the subjective meaning of a concept or a phrase instead of assessing how much the respondent believes in it (Robson, 1994). It is also designed to explore the ratings given along a series of bipolar rating scales (e.g. clean/dirty, I enjoy learning statistics/ I do not enjoy learning statistics). According to Reid (2003), the semantic differential method has the following advantages over the Likert method: its ease of construction, the speed at which it can be answered and that both ends of the scale are defined. Nevertheless, both methods with five or six-point scales are recommended by Reid.

The scaling-techniques approach, where a final score for a respondent is obtained by summing the points from all items, was not adopted in either method used in this study. Reid (2003) points out that '*... adding up a set of such scores may give a number but that number may be fairly meaningless and all the interesting patterns of responses for individual questions are lost*'. Instead, responses to each item were analysed separately.

1. Sex ☐ Male ☐ Female

2. Matric. No . ...

3. Semester of study ....

4. Programme of study
☐ Mathematics education ☐ IT education ☐ Science education and others

5. **Attitudes towards learning statistics**
For each statement below, tick the box that best indicates your opinions about it where
SA = strongly agree A = agree N = neutral D = disagree SD = strongly disagree

	SA	A	N	D	SD
I like to study statistics					
Statistics is easy to learn					
I don't like statistics					
Statistics is easier to learn than other math					
A lot of difficult concepts in statistics					
Have to work hard to master statistical concepts					
Statistics is a challenging subject					
Easier to learn statistics using statistical software packages					

6. I have attended a basic statistics course before ☐ Yes ☐ No

7. In your opinion , is Statistics important ?

☐ Yes because ....

☐ No because ....

8. Please describe in your own words, what you understand statistics is about
....
....

9. **Your opinions on the Statistics course being taught here**
Pairs of contrasting statements are given below with five boxes in between. Tick the relevant box that best represents your opinion. The closest the tick to the statement (either left or right), the strongest the preference.

Easy						Difficult
Interesting lectures						Boring lectures
Heavy workload						Light workload
Tutorials do help						Tutorials don't help
A lot of mathematics involved						Not mathematical enough
Have to use statistical software						Don't have to use statistical software
Too many tests and quizzes						Too few tests and quizzes

Other comments about the statistics course (please specify)
....
....

10. Tick your choices. The closest the tick to the statement (either left or right) , the strongest the preference.

statistics						algebra
statistics						calculus
statistics						discrete mathematics
statistics						english language
statistics						pedagogical studies

11. State the topic/topics in Statistics which you find a) easy b) difficult
....

Figure 6.1: Questionnaire for the student teachers learning statistics

6.3.3 The Digit Span Test

The digit span test is the traditional procedure for determining the working memory capacity (Oberauer, 2003). For the exploratory study, the task was administered in two ways:

- Digit span forward test – It was used only for warming up the participants of the exploratory study and the results of the test were ignored. Participants were read a series of digits and then required to recall and write down the digits in exactly the same order.
- Digit span backward test – Participants were read a series of digits and then were asked to recall and write down the digits in a reverse order or backwards. For example, the series '9, 4, 6, 7' should be written down as '7, 6, 4, 9'.

In both tests, two series of the same number of digits were given and the process continued with the number of digits increased by one at each time until it reached nine digits. Each digit in both tests was read out clearly at a rate of one digit per second and the participants were required to write down the digits into appropriate slots on the answer sheet. The designs and administrative procedures for both tests can be found in Appendix C.

The scoring scheme for the digit backward test was based on the work done by previous researchers (e.g. Case & Globerson, 1974; Su, 1991; Bahar, 1999). The size of an individual's working memory capacity would be determined by the highest number of digits which was correctly recalled (the latter would be referred to as the score for the test). If an individual failed to recall both series with the same number of digits, then the previous successful recall of the number of digits would represent the size of his working memory space. Also, subsequent series containing bigger number of digits would not be considered. An example of a participant who was considered to have a working memory capacity of five units is given below in Figure 6.2.

Number of digits	NUMBERS								
3	6	5	2						√
	5	8	1						√
4	6	9	2	8					X
	6	2	8	5					√
5	7	5	1	6	5				√
	9	3	1	8	7				√
6	3	6	1	8	9	1			X
	5	4	5	0	9	7			X
7	1	5	4	3	6	4	5		-
	7	7	4	3	9	6	2		-
8	4	7	2	2	7	5	1	8	-
	8	9	6	3	2	1	5	3	-

Figure 6.2: An example of a subject's answer sheet in the Digit Span Backward Test.

From previous studies (e.g.: Johnstone & El-Banna, 1986 & 1989; Johnstone *et. al.*, 1993), it was found that the there was a significant correlation between working memory capacity and performance in examinations and problem solving. For clarity, participants in this study were classified into three categories namely: low, intermediate and high working memory capacities. Therefore, to create the categories with roughly the same number of participants in each category (around 33% in each category), the following formula would be used: participants who scored more than one half of a standard deviation above the mean score would be classified as having high working memory capacity while those who scored less than a half standard deviation below the mean score would be classified as having low working memory capacity. Participants whose scores were between the two categories would be classified as having intermediate working memory capacity.

6.3.4 The Hidden Figures Test

The Hidden Figures Test is a version of Witkin's Group Embedded Figures Test (see section 5.3.1) used by many researchers to determine an individual's degree of field dependency (e.g. Su, 1991; Alamolhodaei, 1996; Bahar, 1999). In this test, participants were required to recognise and identify a hidden figure (a simple geometric shape) embedded in a more complex figure. Altogether, there were twenty similar tasks in the test and participants were given about twenty minutes to complete them. The designs and administrative procedures for this test as well as the solutions can be found in Appendix D. The Hidden Figures Test is a valid test to measure field dependency since it is based on the Group Embedded Figure Test which is the criterion measure in this area. From previous studies, reliability coefficient of this test was found to be between 0.71 (Cronbach's finding cited in Su, 1991) and 0.82 (Witkin *et al*, 1971).

For each task, participants would obtain a score of one point if they could identify correctly the required shape embedded in the complex figure. Thus, a participant could score anything from zero to twenty points from the test. The more hidden figures that were correctly found, the better the participant was at this process of separating a figure from a complex background.

According to Liu & Reed (1994), the construct of field dependence/independence describes learners along a bipolar continuum where those at one end are categorised as field dependent and those at the opposite end are said to be field independent, while individuals in the middle range are considered as field intermediate or field neutral. Therefore, based on the scores obtained from this test, participants were classified into three categories: field dependent, field neutral and field independent. From previous studies, it was observed that many cut-offs criteria had been used to classify individuals as being field dependent or field independent. However, to create these categories for this study, a formula derived from the one used by many researchers (e.g. Bahar, 1999; Alamolhodaei, 1996) was employed but with a slight change so that the size of each category would be roughly the same. This new formula is similar to the one used to determine the working memory capacity categories: participants who scored less than a half standard deviation below the mean score would be classified as field dependent while participants who scored more than a half standard deviation above the mean score would be classified as field independent. The rest of the participants whose scores lay in between these two categories would be classified as field intermediate or field neutral.

6.3.5 Structural Communication Grids

Structural communication grids (SCG) in the form of rectangular arrays of possible responses are a powerful assessment technique used as an alternative method for diagnostic and summative assessment (Egan, 1972). As an assessment technique, SCGs have many purposes (Johnstone, 1988; Bahar, 1999):

- To test the ability of respondents to recognise examples of a concept from non-examples, to select information which gives a description, sequence information to give a coherent procedure and to make deductions and inferences from the information given.
- To help respondents to test relationships within the structure of the concepts in their cognitive structure and to enable them to see where their linkages are strong and where they are weak.
- In the classroom, a teacher can have the opportunity to gain insight into a student's thinking and to see where the misconceptions or mislinkages lie in the student's mind.

In the SCG, the data are presented in the form of numbered grids or boxes. The data can be in the form of numbers, formulas, equations, words, phrases, pictures and others. The data represent the solutions to the questions asked. A question can have one or many solutions.

Since a respondent does not know how many boxes are required to answer a question, he has to consider the content of each box and decides which box or boxes may represent the solution or solutions to the question asked. In addition to selecting the correct responses, a respondent can also be asked to list the responses in a correct logical order. Thus, the concern about random guessing by the respondent to get the correct solutions does not arise. In answering the questions by selecting the appropriate boxes, a respondent '*...has stamped his structure upon the random boxes of information to communicate his understanding of the material being tested: hence the name STRUCTURAL COMMUNICATION...*' (Johnstone, 1988)

There are five possibilities in how a respondent can select the boxes. To obtain a full score, he should include all the relevant data only. If he includes most but not all the relevant data, and no irrelevant data, he will get a lesser score. However, if he includes some if not all of the relevant data along with some irrelevant ones, he will get an even smaller score. If he does not give any data, relevant or irrelevant, obviously, he will get no score. Finally, if he includes only irrelevant data, he will get a negative score. To obtain a score for each question, Egan (1972) suggested a formula as follows:

$$\text{Score} = \frac{\text{The number of relevant data chosen}}{\text{The number of relevant data available}} - \frac{\text{The number of irrelevant data chosen}}{\text{The number of irrelevant data available}}$$

By using this formula, a respondent's score for any particular question will range from +1 to –1. For example, suppose a SCG of nine boxes (three rows by three columns) is used (see Figure 6.2). Assuming that an answer to a question requires three boxes and the respondent chooses two correct boxes plus one irrelevant box (out of six), thus the score for this question will be

Score = 2/3 – 1/6 = 0.5

1	2	3
4	5	6
7	8	9

Figure 6.2 An example of a 3 x 3 SCG

For this study, three sets of SCG were given to the participants (see Appendix E). The first set dealt with the basic ideas in descriptive statistics. The second set was concerned with the elementary set theory which is related to probability theory. The third set dealt with axioms and rules of probability. The items were considered valid because they were based on the prescribed introductory statistics syllabus for the student teachers. In addition, face validity was also checked by seeking the opinions of experts. The three sets of SCG were pre-trialled with a group of final-year student teachers (mathematics education) at Sultan Idris Education University who had already taken the introductory statistics course earlier. From this exercise, ambiguities and sources of confusion were identified and SCG sets were then modified. The main purpose of these three sets of SCG was to find out about any misunderstandings or misconceptions the student teachers might have concerning the basic ideas in descriptive statistics and probability theory.

The scoring system used in this SCG test was quite different from the one suggested by Egan in order to simplify the calculation made with the spreadsheet. In this study, responses to each item were coded. The responses given could be in the form of totally relevant data, completely irrelevant or a combination of some relevant and irrelevant ones. Using the spreadsheet, the codes were used to generate a score for each item by using this formula:

$$\text{Score} = \frac{\text{Number of relevant data chosen} - \text{Number of irrelevant data chosen}}{\text{Total number of relevant data available}}$$

For example, if an item had three relevant data and a respondent gave the three exact relevant data and no irrelevant one, then he would obtain a score of 1. However, if he gave one relevant along with two irrelevant ones, he would obtain a score of -0.33. If the number of irrelevant data chosen were greater than the total number of relevant data available, then the number of irrelevant data would be taken to be the same as the total number of relevant data available. This procedure was adopted so as to avoid obtaining a negative score of less than –1. Thus, with this formula, a score for each item will still range from –1 to +1 (similar to the range obtained with Egan's method).

6.4 The Research Questions

The initial aim of this study was to investigate the effects of some psychological factors (working memory and field dependency) on student teachers learning statistics. In addition, their attitudes toward learning statistics as well as their opinions on the statistics course were sought. Thus from this investigation, several questions arise concerning the student teachers learning statistics, the psychological factors and the assessments involving statistics. The questions are as follows:

- Is there any difference between male and female student teachers concerning their attitudes toward learning statistics and their opinions on the statistics course?
- Is there any difference between the Mathematics Education (ME) and Non-Mathematics (NME) student teachers concerning their attitudes toward learning statistics and their opinions on the statistics course?

- Are there any differences in performance between males and females as well as between ME and NME student teachers in each of the following assessment tasks: statistics examination, structural communication grid test, digit span backwards task and hidden figures test?
- Do relationships exist between the various assessment tasks?
- Is there a relationship between size of working memory space and degree of field dependency?
- Does the size of the working memory space relate to the student teachers' performances in statistics examination and structural communication grid test?
- Does the degree of field dependency relate to the student teachers performances in statistics examination and structural communication grid test?
- Is there a relationship between the field dependency categories and the responses given to the items concerning attitudes toward learning statistics and opinions on the statistics course?

6.5. Results and Discussions from the Questionnaire Survey

From the survey, it was obvious that most students (apart from a few who did not respond) agreed statistics was indeed important in everyday life. Typical responses were as follows:

- *Statistics is everywhere especially in the media*
- *You need statistics to understand data, tables and charts*
- *Many jobs require the use of statistics*
- *Statistics is needed for research purposes*
- *To make prediction for the future*

The majority of the student teachers (92.4 %) had had the experience of enrolling in a basic statistics before with their previous colleges or at least had been exposed to elementary statistics at secondary level. Despite this, many still could not describe accurately what statistics is about. Responses to the item '*Describe in your own words what you understand statistics is about*' are shown in Table 6.2

It should be noted that these responses were obtained from an open-ended question. Therefore, the categorisation of them was somewhat subjective. However, it was obvious that most student teachers (more than 50%) surveyed tended to see statistics as most laymen do that is in terms of data descriptions and number crunching. More than 10% saw statistics as the study about probability and only about 12% mentioned statistics as about collecting, analysing and interpreting data. The rest of the respondents described statistics as anything from '*a difficult subject* ' to '*could be anything*'.

Categories	**Number of respondents (N = 295)**	**Percentage of responses**
General calculation	42	14.2
Measurement/evaluation	9	3.1
Finding data/data distribution	63	21.4
Estimation	7	2.4
Making predictions/expectation	9	3.1
Useful thing in daily life	15	5.1
Numerical information	10	3.4
Finding mean, mode, median and std deviation	5	1.7
About graphs, tables and formulas	28	9.5
Probability	32	10.8
Collect, analyse and interpret data	35	11.9
A difficult subject	4	1.3
A branch of mathematics	6	2.0
Relationship among many things	3	1.0
Experiments	2	0.7
An abstract subject	2	0.7
About natural phenomena	2	0.7
Could be anything	2	0.7
No response	19	6.4

Table 6.2: Student teachers' descriptions of what statistics is about

Students were also asked about topics in introductory statistics course that they had encountered so far and perceived as being either easy or difficult to understand. Responses (in percentages) to these questions are presented in Table 6.3.

Topics	**Percentage of respondents who thought topics were easy to understand (N = 295)**	**Percentage of respondents who thought topics were difficult to understand (N = 295)**
Descriptive statistics	71.2	0.7
Probability	12.5	35.9
Discrete distributions	11.5	18.3
Continuous distributions	8.5	17.3
Sampling distributions	1.0	34.9

Table 6.3 Topics that were easy difficult or to understand according to student teachers

Over 70% of the student teachers believed that descriptive statistics was easy to understand compared to just under 1% who thought otherwise. Perhaps the perceived easiness of descriptive statistics was due to the fact that it was mainly concerned with presenting data in the forms of charts and tables and summarising the data using summary measures and ideas of variability. A higher percentage of respondents described probability as a difficult topic to understand rather than an easy one to grasp (35.9% to 12.5%). This was not surprising since probability is often regarded as a particularly difficult concept to learn due to its dealing with uncertainty (e.g. Shaughnessy *et al.*, 1996, Konold, 1991). Most of the respondents did not give any opinion on the last three topics because they were only introduced to them recently. However, more than a third of the respondents (34.9%) thought sampling distributions (the topic that they were studying at that time) a difficult topic to understand.

Responses (shown as percentages of the whole group with N = 295) concerning attitudes toward learning statistics, opinions about the statistics course and preferences between statistics and other disciplines are shown in Table 6.4, Table 6.5 and Table 6.6 respectively.

	SA	A	N	D	SD
I like to study statistics	18.0	48.1	30.8	3.1	0
Statistics is difficult to learn	1.0	27.5	51.2	18.6	1.7
I don't like statistics	0.3	3.7	20.3	55.9	19.7
Statistics is easier to learn than other math	3.1	18.0	43.0	33.6	2.4
A lot of difficult concepts in statistics	2.4	43.7	40.7	12.5	0.7
Have to work hard to master statistical concepts	40.3	49.2	8.8	1.4	0.3
Statistics is a challenging subject	25.8	58.6	12.9	2.4	0.3
Easier to learn statistics using statistical software packages	5.4	22.4	41.4	26.8	4.1

LEGEND:
SA – Strongly Agree **A** – Agree **N** – Neutral **D** – Disagree **SD** – Strongly Disagree
N (Student Teachers) = 295

Table 6.4: Student teachers' responses regarding attitudes toward learning statistics.

From Table 6.4, it was clear that student teachers' attitudes toward learning statistics were generally positive. Just under 4% of them stated their dislike of statistics or studying statistics. However, most of them agreed that statistics is a challenging subject with a lot of difficult concepts and that they had to work hard to master them.

Also, opinions were divided on whether using statistical software would make learning statistics easier.

Easy	7.1	14.9	52.9	16.9	8.1	Difficult
Boring lectures	21.7	29.5	31.9	12.5	4.4	Interesting lectures
Heavy workload	2.7	7.4	38.0	31.9	20.0	Light workload
Tutorials do help	25.1	22.0	30.1	9.5	13.2	Tutorials don't help
A lot of mathematics involved	9.5	21.7	44.4	15.9	8.5	Not mathematical enough
Have to use software	22.7	20.3	40.3	11.5	5.1	Don't have to use software
Too many tests and quizzes	6.8	15.6	59.7	11.9	6.1	Too few tests and quizzes

Table 6.5 Student teachers' responses regarding opinions about their statistics course (N = 295).

From Table 6.6, it appeared that the majority of the student teachers found the statistics course as neither easy nor difficult (52.9%). This might be so because they had only been exposed to a few topics in the syllabus. The perceived difficulty of probability was balanced by the students' perception of descriptive statistics as being easy to understand. Just over a half (51.2%) thought that the lectures delivered by the lecturer were boring. One of the reasons might be due to the teaching strategy employed by the lecturer. No discussion was involved and the lectures were delivered through prepared notes using the overhead projector. Also, student teachers were not exposed to the usage of statistical software such as SPSS or Minitab in the classroom.

Tutorial classes were thought to be helpful. The classes were held once a week in an informal way where student teachers sought clarifications from the tutor about certain aspects in the lectures that they did not understand and also to seek help with the problem sheets given to them weekly. Just under a third of the student teachers thought that the course was too mathematical. A brief look at the course's syllabus revealed that mathematics components like algebra and calculus were indeed required. In addition, much emphasis is given to routine computational problems in statistics.

Apart from the items in Table 6.5 above, student teachers also stated, in their own words, opinions about the statistics course. The following selections of the student teachers' written comments highlighted some of the most frequently expressed opinions.

- *Make lectures livelier and more interesting*
- *Should explain concepts more clearly and the lectures should be delivered in a slower pace.*
- *Notes outlining the concepts and worked examples should be handed out earlier (preferably at the end of the previous lecture).*
- *Lecture time should be devoted to explaining statistical concepts and relate them to real-life examples.*
- *More examples should be given and the computational procedures shown clearly.*
- *The lecturer should not assume that students have the same level of knowledge about statistical concepts and theories.*
- *Students should be taught how to use statistical software so as to minimise time spend on doing tedious calculations and drawing graphs.*
- *The course should involve less mathematics and should do away with calculus.*
- *The lecturer should employ more variety in his teaching method by including small groups' discussion and also practical activities in the classroom.*
- *Tutorial classes should be increased from once to twice a week and the size of each class should be small.*

statistics	8.1	10.8	37.6	16.9	26.4	algebra
statistics	16.6	21.4	30.5	14.2	17.3	calculus
statistics	14.9	21.0	44.1	11.5	8.5	discrete mathematics
statistics	26.8	32.9	18.6	9.5	12.2	english language
statistics	15.6	14.2	38.3	16.6	15.3	pedagogical studies

Table 6.6: Student teachers' preferences between statistics and some other disciplines (N = 295).

To gauge the popularity of the statistics course, student teachers were asked about their preferences between statistics and some other compulsory disciplines required for their Bachelor of Education degree course (see Table 6.6). A higher percentage of them chose statistics over calculus, discrete mathematics or English language. Content wise, calculus and discrete mathematics were technically more difficult than statistics. Thus, this result was not really surprising. English Language courses, compulsory to all student teachers in their first three semesters, was less favoured because English is a foreign language and also the courses involved a lot of assignments such as essay writing and reading. On the other hand, algebra was more preferred to statistics. One of the reasons was perhaps due to the precise and finite nature of algebra which was markedly different from statistics (especially probability) that dealt with uncertainty and indeterminacy (Gal & Garfield, 1997).

6.5.1 Comparisons between Gender and between Programmes of Study

Differences between male and female student teachers as well as between the Mathematics Education (ME) and the Non-Mathematics Education (NME) groups regarding the responses to the questionnaire were also explored and analysed using the chi-square (χ^2) test (see Appendix Q). The results are summarised below:

- There were no relationships between gender and the responses to the items relating to attitudes toward learning statistics except for the items '*Statistics is difficult to learn*' ($\chi^2 = 14.4$, df = 2, $p < 0.01$).and '*Have to work hard to master the statistical concepts*' ($\chi^2 = 4.4$, df = 2, $p < 0.05$) where male student teachers tended to agree more with the statements.
- Regarding the student teachers' opinions on the statistics course, there were relationships between gender and the responses to the following items:

    1. '*Boring lectures/ Interesting lectures*' ($\chi^2 = 10.9$, df = 2, $p < 0.01$). A higher proportion of the male than the female student teachers found the lectures to be boring.
    2. '*Heavy workload/ Light workload*' ($\chi^2 = 6.1$, df = 2, $p < 0.05$). A higher percentage of female student teachers than male counterparts believed that the course entailed light workload.
    3. '*A lot of mathematics involved/ Not mathematical enough*' ($\chi^2 = 6.9$, df = 2, $p < 0.05$). More female student teachers than male student teachers believed that the course was not mathematical enough.
    4. '*Have to use statistical software/ Don't have to use statistical software*' ($\chi^2 = 10.5$, df = 2, $p < 0.01$). A higher proportion of female student teachers agreed that the usage of statistical software packages was necessary.

- There were no relationships between gender and responses to the items on 'Your Preference' except on the item '*statistics/ algebra*' ($\chi^2 = 10.5$, df = 2 , p

< 0.01. A significantly higher percentage of female student teachers preferred algebra to statistics.

- There were no relationships between programme of study and responses to items on attitudes toward learning statistics except on this item: '*Easier to learn statistics using statistical software*' which favoured the NME group ($\chi^2 = 13.0$, df = 2, $p < 0.01$).
- There were significant relationships between programme of study and responses to the following items on student teachers' opinions on the introductory statistics course:

    1. '*Easy/ Difficult*' ($\chi^2 = 6.8$, df = 2, $p < 0.05$). A higher proportion of NME student teachers than ME student teachers believed that the statistics course was difficult.
    2. '*Tutorials do help/ Tutorials don't help*' ($\chi^2 = 10.1$, df = 2, $p < 0.01$). A higher proportion of the student teachers in the NME group acknowledged that the tutorials did help them.
    3. '*Too many tests and quizzes/ Too few tests and quizzes*' ($\chi^2 = 10.6$, df = 2, $p < 0.01$) About 32% of the NME student teachers believed that the course had too many tests and quizzes when compared to only 16% of the ME student teachers..

- On student teachers' preferences between statistics and some other disciplines, there were relationships between programme of study and responses to the following items:

    1. '*statistics/ algebra*' ($\chi^2 = 22.3$, df = 2, $p < 0.001$). The percentage of ME students who preferred statistics was significantly lower than NME students.
    2. '*statistics/ discrete mathematics*' ($\chi^2 = 16.7$, df = 2, $p < 0.001$). The percentages of student teachers from both groups who preferred statistics were about the same but a significantly higher percentage from the NME group chose discrete mathematics than those from the ME group. This was possibly due to the contents of the discrete

mathematics course which was related to the computer and information technology courses.

3. '*statistics/ pedagogical studies*' (χ^2 = 16.7, df = 2, p < 0.001). There were significantly higher percentage of student teachers from NME who preferred pedagogical studies than those from the ME group.

From the results described above, it appeared that the statistics course was not favoured by the male student teachers who found it difficult to learn with boring lectures and heavy workload. Thus, it was not surprising that almost half of them saw the need to use statistical software packages to help them in their learning of statistics. On the other hand, only one in seven of the female student teachers thought that it was difficult to learn statistics although they too believed (to a lesser degree than their male counterparts) that the statistics course's lectures too were boring. It is interesting to note that despite the difficulty the male student teachers faced in the statistics course, an overwhelming majority of them liked to study statistics. Perhaps, if the statistics course was not boring, the content was less mathematical and the lecturer made the effort to have the lessons in statistics interesting by employing various strategies, then the male student teachers might not think of statistics as being difficult to learn.

The statistics course was also perceived as being difficult by student teachers from the Non-Mathematics Education programmes. Again, this was not surprising since the content of the course was seen as too mathematical to them. However, they appreciated the tutorials that were held weekly in helping them in learning statistics especially with the computational techniques. In addition, they strongly believed that using the statistical software packages would make the learning of statistics to be easier. This was expected since the majority of the Non-Mathematics education programme student teachers were from the Information Technology Education programme.

In general, the introductory statistics course needed to be revamped so that it would appeal to all student teachers who were studying them. It should be made less mathematical, should emphasise statistical concepts rather than computational techniques and should employ various teaching strategies to make it more interesting and relevant to everyday life.

6.6 Analysis of the Statistics Examination Scores

The end-of-semester overall marks for the statistics course comprised the class quizzes (20%), mid-term test (20%) and the final examination (60%). The overall marks shall now be referred to as the statistics examination scores whose distribution is shown in Figure 6.4 below.

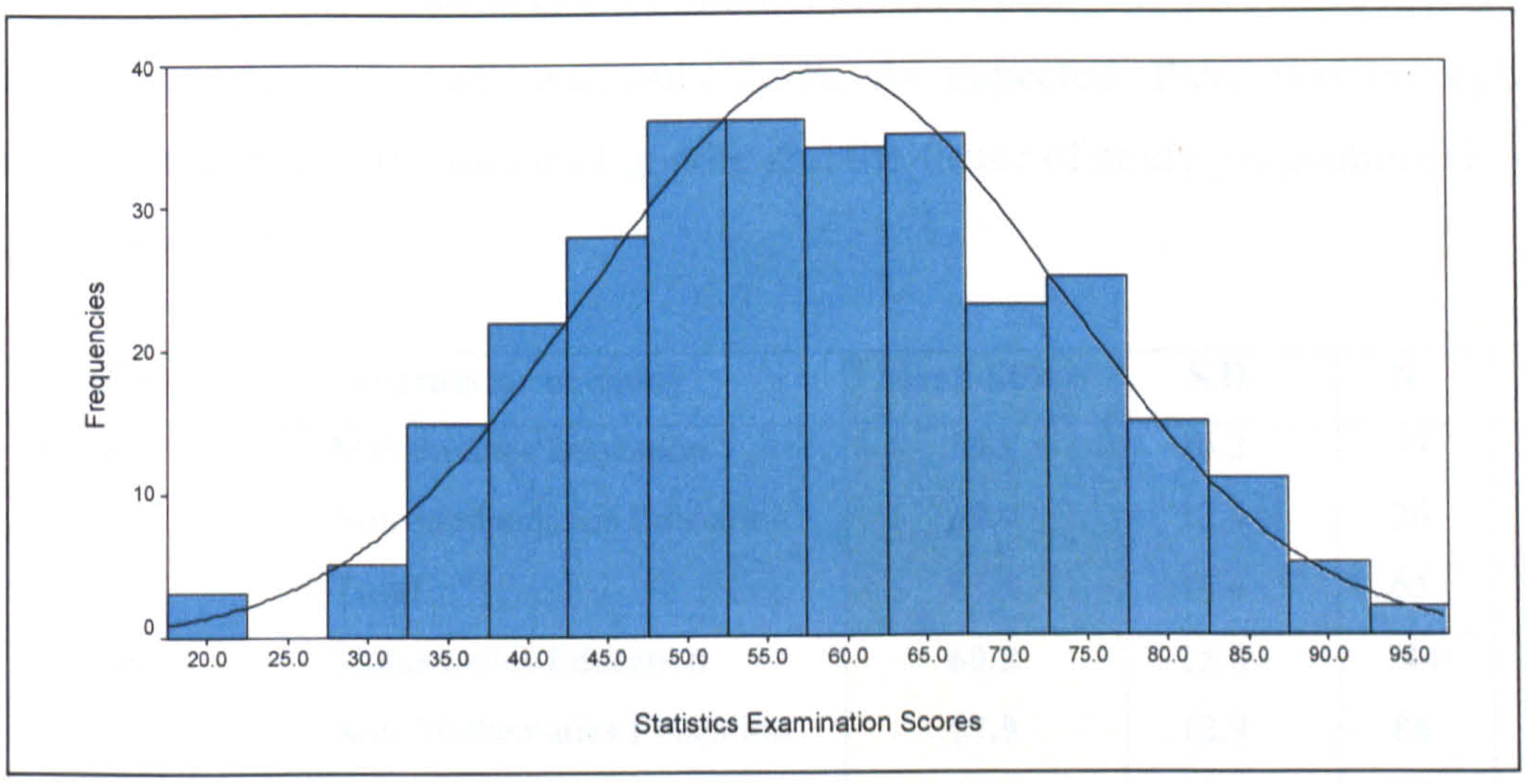


Figure 6.4: The distribution of the statistics examination scores

From the histogram, it is evident that the statistics examination scores were normally distributed with a mean score of 58.5 and a standard deviation of 14.9. The minimum score was 16 while the maximum score was 94. Student teachers who obtained a score of 40 and above were deemed to have passed the introductory statistics course.

6.6.1 Comparisons between Gender and between Programmes of Study

The effects of gender and programme of study on the statistics examination scores were also analysed by employing the 2 x 2 (2 factors and 2 levels) between-subjects ANOVA (analysis of variance) design. *The hypothesis tested was that there would be no difference between the examination scores obtained by the male and female student teachers and between ME and NME groups.*

It was found that there was a significant main effect of gender on statistics examination scores ($F_{(1, 291)} = 4.27$, $p < 0.05$). The mean score for female student teachers was significantly higher than their male counterparts (see Table 6.7). There was also a significant main effect of study programme which favoured the ME group ($F_{(1, 291)} = 5.44$, $p < 0.05$) (see Figure 6.4.and Table 6.7). A correlational analysis (using point biserial correlation coefficient) also revealed significant relationships at 5% level between statistics examination scores and gender ($r_b = 0.12$, $n = 295$, $p < 0.05$, two-tailed) and between statistics examination scores and programme of study ($\rho = 0.12$, $n = 295$, $p < 0.05$, two-tailed). Nevertheless, both correlation coefficients were low and from the multiple regression analysis, it was found that the proportion of the variance in the statistics examination scores which was accounted for by gender and programmes of study was only 2.5%. As expected, there was no significant interaction between the factor of gender and the factor of study programme ($F_{(1, 291)} = 1.58$, $p = 0.209$).

Gender	Programme of Study	Mean Score	S.D	N
Male	Mathematics Education	**58.5**	16.2	39
	Non-Mathematics Education	**50.9**	12.4	26
	Total	**55.4**	14.6	65
Female	Mathematics Education	**60.2**	15.8	144
	Non-Mathematics Education	**57.9**	12.9	86
	Total	**59.3**	14.8	230
Total	Mathematics Education	**59.8**	15.9	183
	Non-Mathematics Education	**56.3**	12.7	112

Table 6.7: The distribution of the statistics examination scores and standard deviations according to gender and programmes of study

6.6.2 Relationships between the Statistics Examination Scores and Student Teachers' Attitudes

A correlational analysis was carried out to determine the relationship, if any, between the statistics examination scores and student teachers' attitudes toward learning statistics as well as their opinions regarding the statistics course. Since the attitudes and opinions that were assessed produced ordinal measures, a non-parametric correlation coefficient was used (either Spearman's rho or Kendall's tau-b). In this analysis, Spearman's rho was used. The full results of the analysis can be found in Appendix R. Surprisingly, there was no relationship between the statistics examination scores and most of the questionnaire items on student teachers' attitudes toward learning statistics. The only significant relationship was with the item 'Have to work hard to master statistical concepts' although the correlation coefficient was low ($\rho = 0.16$, $n = 295$, $p < 0.01$, two-tailed). One would expect to find a positive relationship between student teachers who agreed to the statements like 'I like to study statistics' and the statistics examination scores or a negative relationship between the statement 'Statistics is difficult to learn' and the statistics examination scores. However, this was not the case and perhaps it could be concluded that student teachers' attitudes toward learning statistics seemed to have no effect on their performance in statistics examination if the student teachers really responded honestly in the questionnaire.

On student teachers' opinions about their statistics course, there were only two items that correlated significantly with the statistics examination scores. The items were 'Boring - Interesting' ($\rho = 0.14$, $n = 295$, $p < 0.05$, two-tailed) and 'A lot of mathematics involved - Not much mathematics involved' ($\rho = 0.15$, $n = 295$, $p < 0.01$, two-tailed). Student teachers who described the statistics course as boring were likely to perform worse than those who described otherwise. This might seem reasonable because boring lectures were unlikely to motivate the student teachers to learn statistics and this might lead them to perform badly in tests and examination. Student teachers who thought that the contents of the statistics course were too mathematical were likely to perform worse than those who believed that the contents were less mathematical. The former, especially from the non-mathematics backgrounds might be turned off by the very mathematical nature of the statistics course and thus would struggle to do well in the assessments.

6.7 Analysis of the Results from the SCG Test

Although the items asked in the SCG test (see Appendix 6 and Figures 6.5, 6.6, 6.7) were quite straightforward and required minimal or no calculation at all, the results obtained were not encouraging. In fact, none of the items registered a hundred percent correct response from the student teachers. Table 6.8 gives the facility value (FV- the proportion of respondents answering the item correctly) for each item.

Item	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	C4	C5
FV	0.17	0.72	0.03	0.34	0.85	0.86	0.93	0.22	0.46	0.54	0.46	0.29

Table 6.8: The facility values to items in the SCG test

Use the boxes to answer the following questions. Each box may be used more than once. Use the numbers 1,2,...,9 to represent the boxes

1 standard deviation	2 median	3 range
4 mean	5 first quartile	6 variance
7 third quartile	8 mode	9 inter quartile range

A1. Which boxes contain the measures of location?

Answer: 2, 4, 8

A2. Which box represents the quantity that measures the difference between the largest value and the smallest value?

Answer: 3

A3. Apart from the smallest value and the largest value from a set of data, which other boxes are needed to construct a box plot?

Answer: 5, 2, 7

A4. To calculate quantity Y, one has only to find the positive square root of quantity X if it is known. Which boxes represent X and Y respectively ?

Answer: 6, 1

Fig. 6.5: SCG Test (Grid A)

The first set of the SCG test (Grid A) dealt with some factual knowledge about descriptive statistics. Only 17% of the student teachers managed to name all three measures of central tendency correctly (Item A1). Some managed to name only one correct response (mostly 'mean') or a combination of two of them (for example 'mean' and 'median'). Other answers involved a variety of combinations such as one correct response plus two incorrect responses (for example, 'mean', 'range', 'variance'). The facility value for item A2 was quite high which meant that most respondents knew what the term 'range' meant in statistics. The item where respondents were asked to name the measures required to construct a box plot (apart from the minimum and maximum values), proved to be the one with the lowest facility value (Item A3). Just under 3% got all the correct responses for that item. In item A4, just over a third of the respondents managed to identify *that standard deviation (quantity Y) is the value that represents the positive square root of variance (quantity X)*. Other responses that were incorrect included 'variance' and 'mean' or 'range' and 'inter quartile range'. Overall, the performances of the student teachers in this section were quite poor. All the items required respondents to recall some facts about certain measures in descriptive statistics. It seems that most of the student teachers had not remembered what they had presumably learned from the statistics lectures.

A group of students from UPSI wish to have a picnic by the riverside.
Let X represents 'the weather would be fine'; Y represents the event that 'food brought would be sufficient' and Z represents the event that 'the picnic would be fun'.

The grid below consists of various events that are associated with the above events.

1 X'	2 Y'	3 Z'
4 $X \cap Y$	5 $X \cap Z$	6 $Z \cap Y$
7 $X \cap Z \cap Y'$	8 $X \cap Y \cup Z$	9 $X' \cup Z \cup Y'$

State the box or boxes which appropriately describe the events below.

B1. The weather is nice and the picnic is fun but the food is not enough.
Answer: 7

B2. The food is sufficient and the picnic is fun
Answer: 6

B3. The weather would be bad
Answer: 1

Fig. 6.6: SCG Test (Grid B)

The second set of the SCG test (Grid B) was about probability events that were compounded by forming union, intersection or complement. All three items had high facility values which might indicate that majority of the student teachers did not have difficulties in representing probability events with symbols from the set theory. This was expected since the problems posed were straightforward and neither difficult nor challenging enough for them. It appeared that the majority of the student teachers knew what the symbols $\cup$, $\cap$ and X' represented.

The grid below contains various values of p (probability) for the occurrence of certain events. Use the numbers from the boxes to answer the following questions. Each box may be used more than once.

1 $p = 0$	2 $p = 1$	3 $p > 1$
4 $0 \leq p \leq 1$	5 $p < 0$	6 $p = ½$
7 $½ < p \leq 1$	8 $0 < p < ½$	9 $-1 < p < 1$

C1. Which boxes contain impossible values for p?

Answer: 3, 5, 9

C2. Which box denotes that an event is certain to happen?

Answer: 2

C3. Which box denotes that an event is definitely not going to happen?

Answer: 1

C4. Suppose there are 30 students in a class comprising 15 girls and 15 boys. A teacher wants to choose a student at random from that class. Which box represents the exact probability that a girl is chosen?

Answer: 6

C5. Now the teacher decides to choose two students at random. Which boxes represent the likely probability that two boys are chosen?

Answer: 4, 8

Fig. 6.7: SCG Test (Grid C)

The third set of the SCG test (Grid C) dealt with basic probability rules and also involved rudimentary calculations. Only 22% correctly identified that probability values did not belong into these inequalities: $p < 0, p > 1, -1 < p < 0$ (Item C1) It was evident that most respondents had difficulty in remembering or did not know that probabilities are real numbers between 0 and 1, inclusive. This also meant that to some respondents, values outside this range; $0 \leq p \leq 1$, were acceptable as values representing probabilities. About 46% correctly chose $p = 1$ as the probability that an event is certain to happen (Item C2) and a higher percentage (54%) pointed out accurately that the probability an event is definitely not going to happen is 0 (Item C3). Items C4 and C5 involved some basic calculations and the facility values were 0.46 and 0.29 respectively. In item C4, respondents should use the classical probability concept to calculate the probability that a girl is chosen at random from a class comprising of 15 girls and 15 boys. However, more than 50% of the respondents calculated the probability as being either $p > ½$ or $p < ½$. The last item C5, with a facility value of 0.29 required respondents to use the general multiplication rule to calculate the probability that two events would both occur. Overall, the performances of the student teachers in this section of the SCG test were not satisfactory despite the fact that the items merely asked them to recall some basic rules of probability and to do some very straightforward calculations.

A number of underlying reasons could be behind the student teachers' less than satisfactory performances in the SCG test especially in the first and third sets. As mentioned earlier, one possible explanation was that the student teachers tended to forget what they learned once the lectures were over. Some might memorise the facts from the lectures without really understanding them. Thus, without understanding, the ability to retain what they learned would diminish (Hiebert & Carpenter, 1992). The other reason could be due to the assessment procedures of the structural communication grids where respondents have to determine for themselves the number of boxes to be picked to obtain the correct answers for any item. Thus, some student teachers might find it difficult to distinguish the relevant boxes from the irrelevant ones in order to get the correct response to a particular question.

The distribution of the SCG test scores is shown in Figure 6.8 below with a mean score of 4.3 and the standard deviation was 3.3. The best score was 11.0 (out of a maximum 12.0) and the worst score was - 4.7. The assumption for normality for this distribution seems not unreasonable.

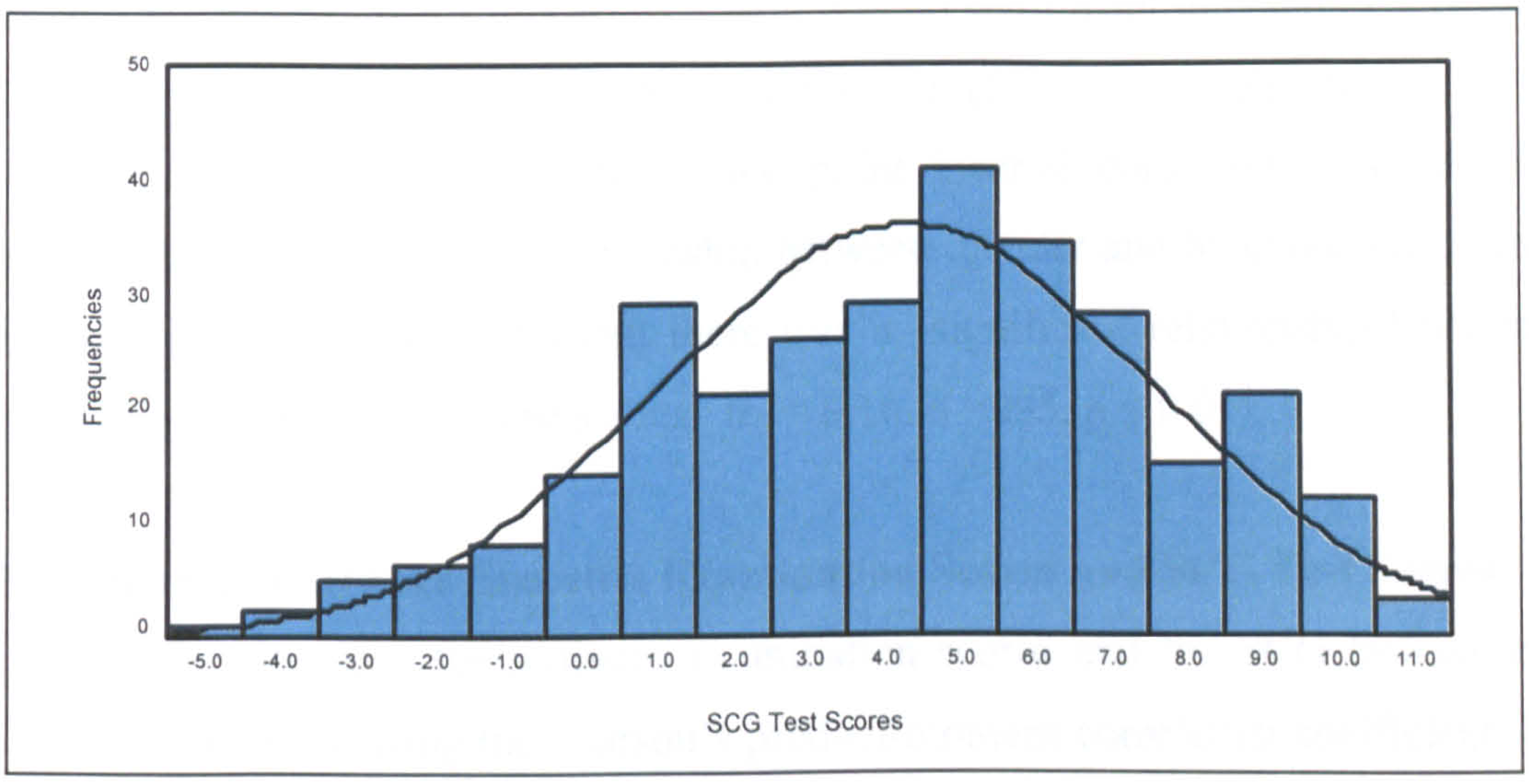


Figure 6.8 The Distribution of the SCG Test Scores

6.7.1 Comparisons between Gender and between Programmes of Study

The effects of gender and programme of study on the SCG test scores were analysed by employing the 2 x 2 (2 factors and 2 levels) between-subjects ANOVA design. *The hypothesis tested was that there was no difference between the mean score obtained by female and male student teachers as well as between ME and NME student teachers.* Table 6.9 shows the distribution of the mean scores and standard deviations by gender and by programme of study.

Gender	Programme of Study	Mean Score	S.D	N
Male	Mathematics Education	16.2	3.6	39
	Non-Mathematics Education	15.8	3.5	26
	Total	16.0	3.6	65
Female	Mathematics Education	16.7	3.2	144
	Non-Mathematics Education	15.6	2.9	86
	Total	16.3	3.1	230
Total	Mathematics Education	16.6	3.3	183
	Non-Mathematics Education	15.7	3.0	112

Table 6.9: The distribution of the SCG test mean scores and standard deviations according to gender and programmes of study

Although the mean score for female student teachers was higher than the male student teachers, the difference was not significant ($F_{(1, 291)} = 0.12$, df = 1, $p = 0.729$). On the other hand, there was a significant main effect of programme of study on SCG test scores ($F_{(1, 291)} = 5.77$, df = 1, $p < 0.05$). There was no significant interaction between gender and programme of study on SCG test scores ($F_{(1, 291)} = 0.51$, df = 1, $p = 0.476$). A correlational analysis (using the point biserial correlation coefficient) seemed to confirm there was no relationship between gender and SCG test scores ($r_b = 0.01$, $n = 295$, $p = 0.824$) and that there was a significant relationship between programme of study and SCG test scores ($r_b = 0.16$, $n = 295$, $p < 0.01$).

6.7.2 Relationship between Statistics Examination Scores and SCG Test Scores

The relationship between the statistics examination scores and the SCG test scores was also examined by using the Pearson's product-moment correlation coefficient. It was found that the correlation between the two variables was significant at 0.1% level but relatively low ($r = 0.34$, $n = 295$, $p < 0.001$, two-tailed). A scatterplot depicting the relationship between the two variables is shown in Figure 6.9 below.

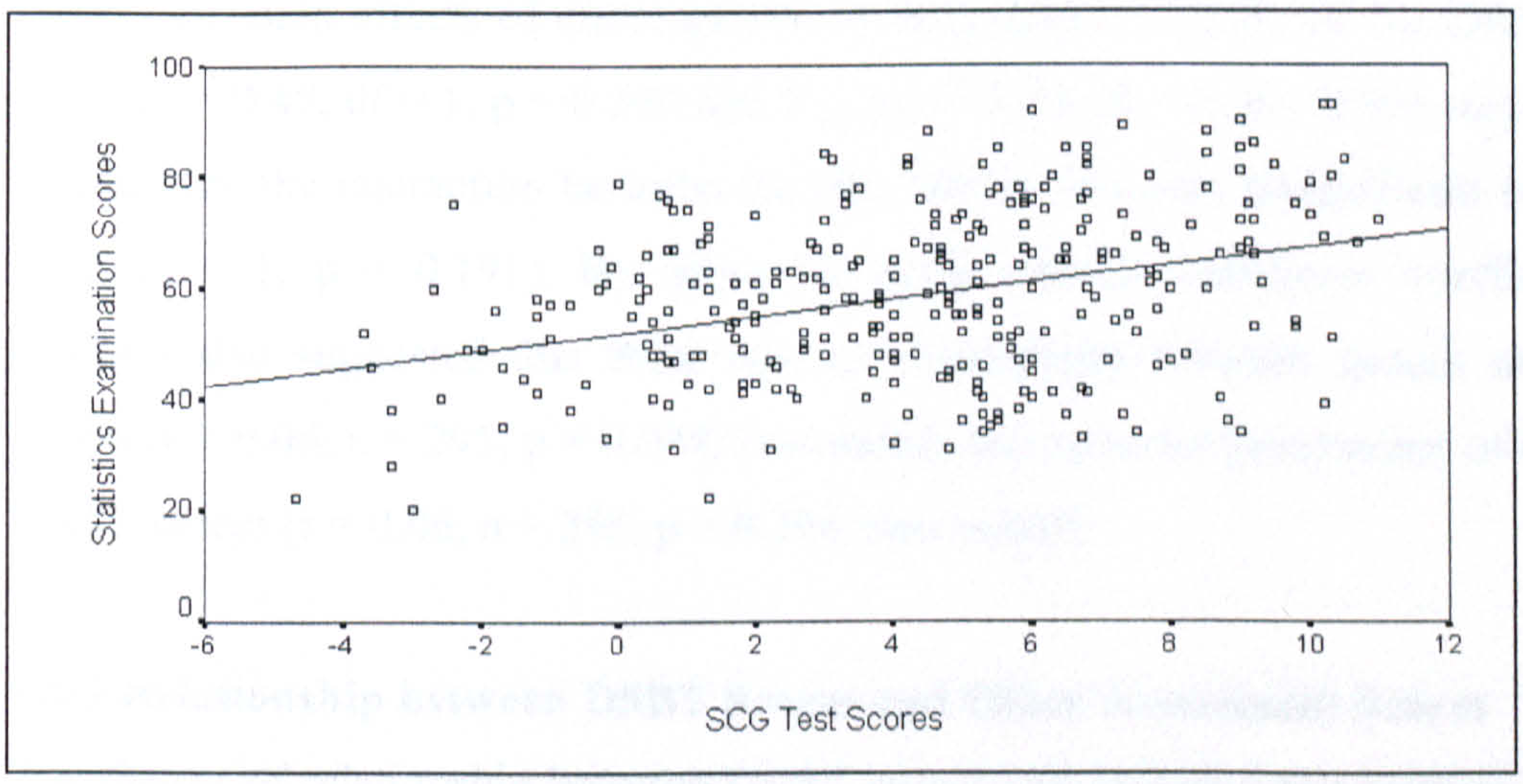


Figure 6.9: Scatterplot showing the relationship between statistics examination scores and SCG test scores

6.8 Results from the Digit Span Backward Test (DSBT)

The distribution of the Digit Backward Span Test scores for all 295 respondents is shown in Figure 6.10 below with a mean score of 7.0 and standard deviation of 1.3. The minimum, median and maximum scores are 2, 7 and 9 respectively. The distribution seemed to be skewed to the left because some outliers (scores less than 4) were present.

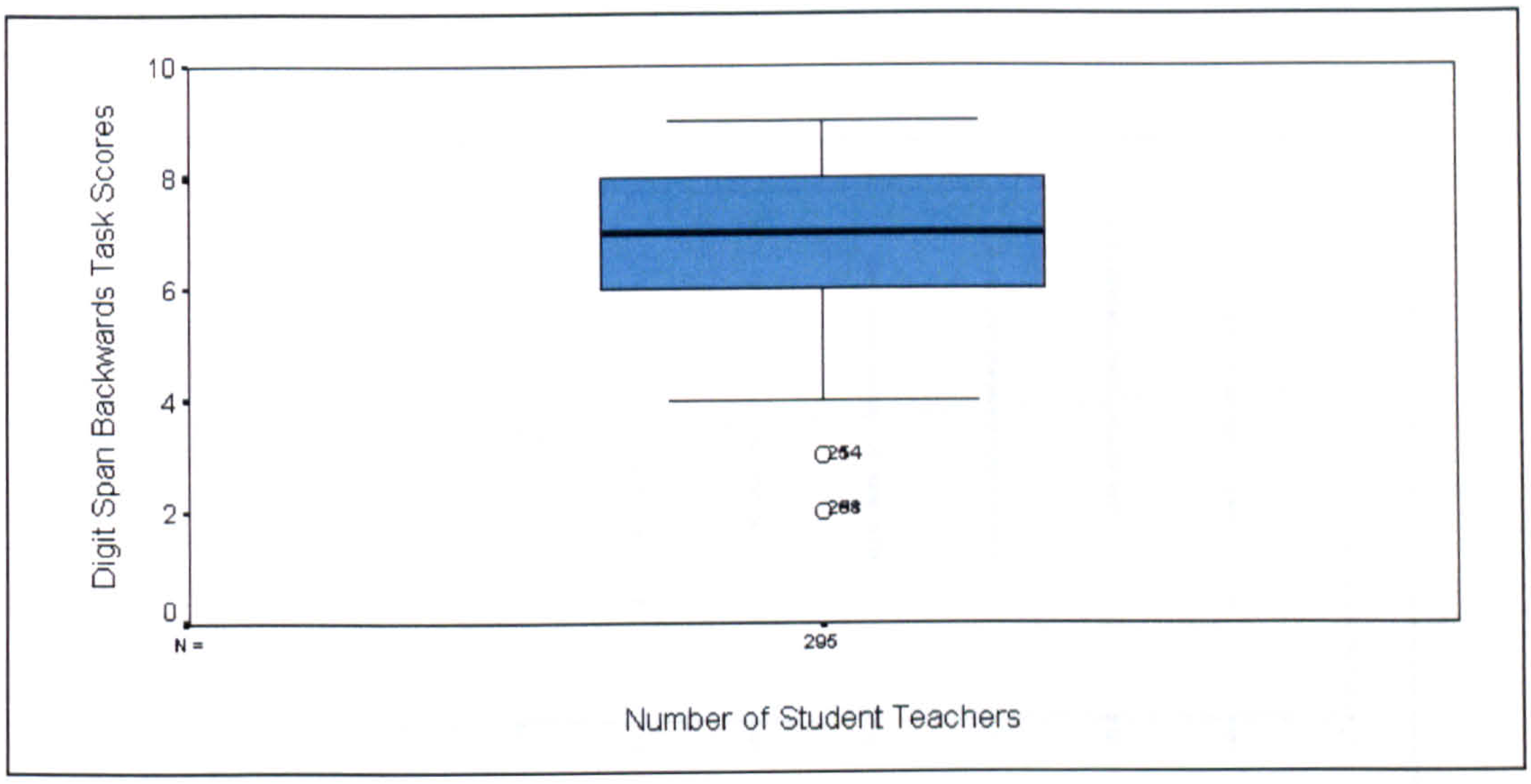


Figure 6.10: The distribution of the DSBT scores (N.B: O^{254} and O^{288} are outliers)

6.8.1 Comparison between Gender and between Programmes of Study

Using the 2 x 2 between subjects ANOVA design, it was found that there were no significant main effects of either gender or programme of study on the DBST scores ($F_{(1, 291)} = 0.45$, df = 1, p = 0.503 and $F_{(1, 291)} = 0.00$, df = 1, p = 0.991 respectively). In addition, the interaction between the two factors was also insignificant ($F_{(1, 291)}$ = 1.72, df = 1, p = 0.191). By using the point biserial correlation coefficient, the analysis also suggested that there was no relationship between gender and DBST scores (r = 0.06, n = 295, p = 0.344, two-tailed) and between programme of study and DSBT scores (r = 0.06, n = 295, p = 0.294, two-tailed).

6.8.2 Relationship between DSBT Scores and Other Assessment Scores

The degree of relationship between DSBT scores and statistics examination scores as well as between DSBT scores and SCG test scores was measured by using the Pearson's product-moment correlation coefficient (denoted by r). It was found that there was a significant correlation between DBST sores and statistics examination scores (r = 0.12, n = 295, $p < 0.05$, two-tailed). Although the correlation coefficient was low, it could be inferred that student teachers with high working memory space tended to perform better in statistics examination. The relationship between these two variables is shown by the scatterplot in Figure 6.11. There was no significant relationship between DSBT and SCG test scores (r = 0.07, n = 295, p = 0.218, two-tailed). It seemed that items in the SCG test did not exceed anybody's working memory capacity.

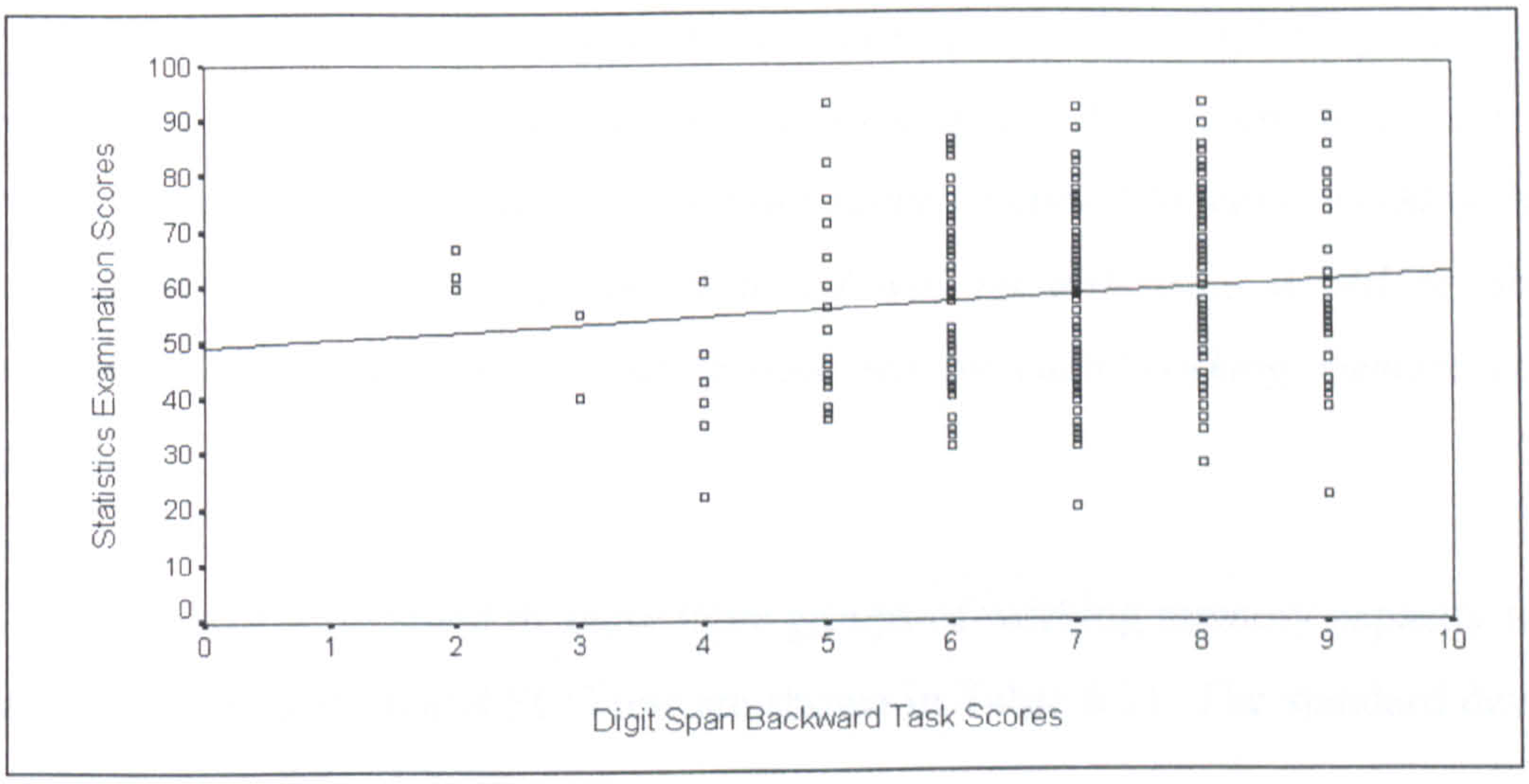


Figure 6.11: Scatterplot showing the relationship between statistics examination scores and DSBT scores.

6.8.3 The Working Memory Capacity Categories

Based on the distribution of the DSBT scores, the student teachers were divided into 3 groups representing their levels of working memory capacity. Using the formula mentioned in 6.3.2, student teachers who correctly recalled up to 6 digits were categorised as having low working memory capacity (X = 6) while those who recalled 8 or more digits (X = 8) correctly were categorised as having high working memory capacity .The intermediate category between these two categories represented those who correctly recalled exactly 7 digits (X = 7) which was incidentally the mean score and also the median for the distribution of the DBST scores. The categorisation of the student teachers into working memory capacity groups is shown in Table 6.10.

Category	No. of student teachers
Low Working Memory Capacity (X = 6)	83 (28.1%)
Intermediate Working Memory Capacity (X = 7)	105 (35.6%)
High Working Memory Capacity (X = 8)	107 (36.3%)

Table 6.10: Categorisation of the student teachers into working memory capacity groups

Since the correlational analysis revealed that there was a significant but low correlation between DSBT scores and statistics examination scores but no relationship between DSBT scores and SCG test scores, it would be interesting to see whether the mean scores for both statistics examination and SCG test were significantly different between the three working memory capacity groups by employing the one-way between-subjects ANOVA design. *The hypothesis tested was that there would be no difference in mean statistics examination score obtained by each working memory capacity group. Another hypothesis tested was no difference would be observed regarding the mean SCG test score obtained by each working memory capacity group.*

The mean scores obtained by these three groups of working memory capacity for both statistics examination and SCG test are shown in Table 6.11. The standard deviations are given in italic and in brackets.

Working Memory Capacity Groups	Statistics Exam Mean Score & SD	SCG Test Mean Score & SD
X = 6	56.2 (*15.4*)	3.9 (*3.5*)
X = 7	58.7 (*14.8*)	4.3 (*3.0*)
X = 8	60.2 (*14.2*)	4.6 (*3.2*)

Table 6.11: The distribution of the mean statistics examination scores and the mean SCG test scores according to working memory capacity groups

From the table, student teachers in the high working memory capacity group produced the best mean scores in both statistics examination while those in the low working memory capacity group had the worst mean scores. However from the ANOVA design, it was found that the differences among the statistics examination mean scores for the three groups were not significant ($F_{(2, 292)} = 1.677$, df = 2, p = 0.189). Nevertheless, this might be a good thing since it indicated that the items in the examination might had already taken working memory into account and thus did not overly burden the student teachers' working memory. Similarly, it was also found that the differences among the SCG mean scores for the three groups were not significant ($F_{(2, 292)} = 0.876$, df = 2, p = 0.418). Again, this shows that the items in the SCG test did not really overstretch the student teachers' working memory.

6.9 Results from the Hidden Figures Test (HFT)

The distribution of the HFT scores for all participants is shown in Figure 6.12 below with a mean score of 8.7 and a standard deviation of 3.7. The minimum, median and maximum scores are 0, 8 and 20 respectively. The distribution of the HFT scores looks skewed to the right because of the presence of some outliers (scores greater than 17).

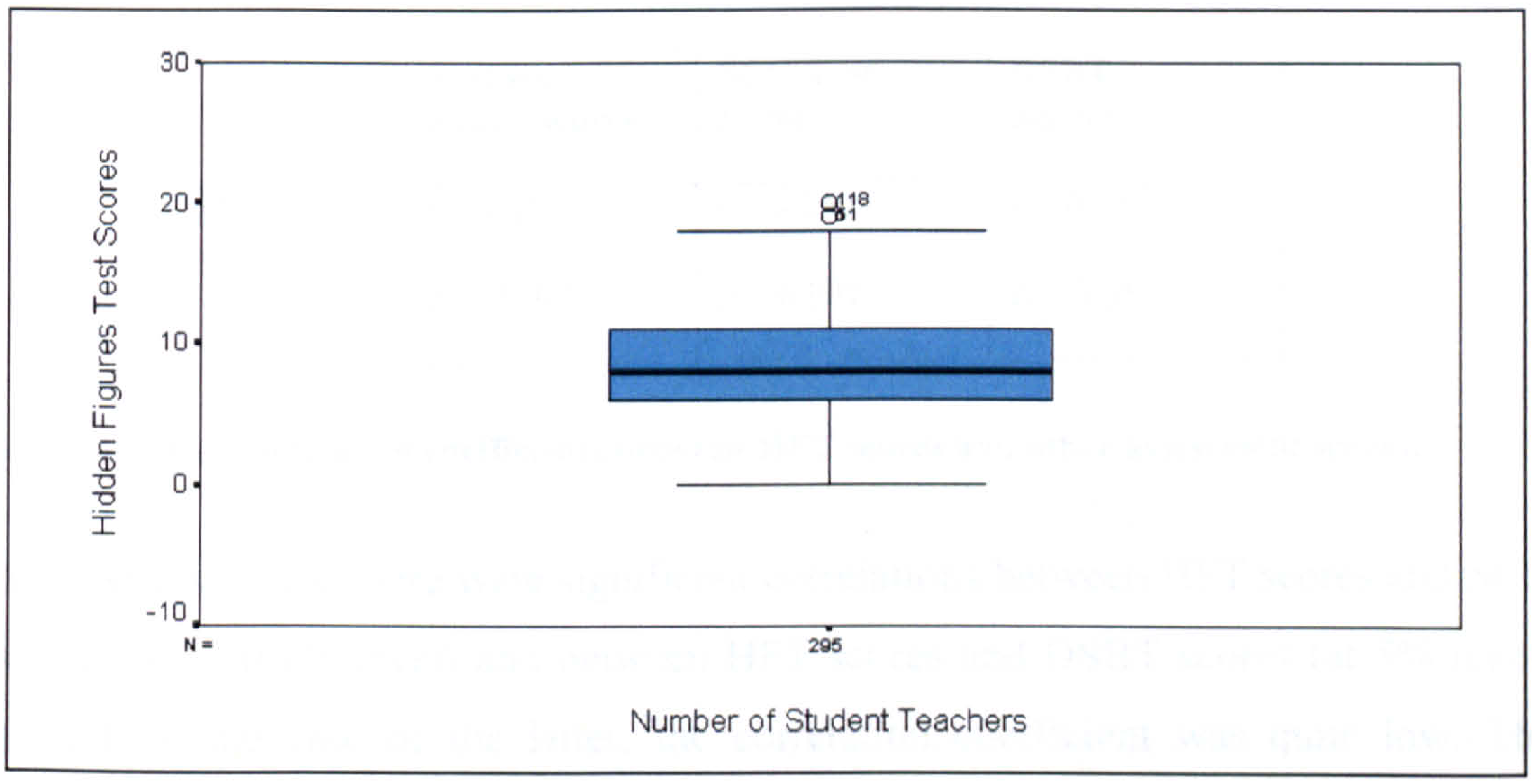


Figure 6.12: The distribution of the Hidden Figures Test scores (NB: O^{51} and O^{118} are outliers)

6.9.1 Comparisons between Gender and between Programmes of Study

As with other assessment tasks, a two-way between-subject ANOVA design was used to study the effects of either gender and/or programme of study on the HFT scores. *The hypothesis tested was that no difference was observed between the mean score obtained by female and male student teachers as well as between ME and NME student teachers.*

It was found that there were no significant effects of all the factors (gender, programme of study and the interaction between gender and programme of study) on the HFT scores ($F_{(1, 291)} = 0.019$, df = 1, p = 0.891; $F_{(1, 291)} = 1.344$, df = 1, p = 0.247 and $F_{(1, 291)} = 0.843$, df = 1, p = 0.359 respectively). The correlational analysis using the Spearman's rho coefficient also suggested that there was no relationship between the HFT scores and either of gender or programme of study (ρ = 0.095, n = 295, p = 0.103, two-tailed and ρ = 0.058, n = 295, p = 0.319, two-tailed respectively)

6.9.2 Relationship Between HFT Scores and Other Assessments' Scores

By employing the Pearson product-moment correlation coefficient, the degree of relationship between the HFT scores and each of the assessment task's scores (statistics examination, SCG test and DSBT) was measured. The correlation coefficients, the p-values and their levels of significance are shown in Table 6.12 below.

	Statistics Exam Scores	SCG Test Scores	DSBT Scores
HFT Scores	$r = 0.10$ $p = 0.100$	$r = 0.259$ $p < 0.001$	$r = 0.12$ $p < 0.05$

Table 6.12: The correlation coefficients between HFT scores and other assessment scores.

It was observed that there were significant correlations between HFT scores and SCG test scores (at 0.1% level) and between HFT scores and DSBT scores (at 5% level) although in the case of the latter, the correlation coefficient was quite low. The significant relationship between HFT scores and SCG test scores was expected because of the nature of the SCG test where the respondents were required to discern the relevant information from the 'noises' in order to pick out the correct answers. Although significant, the low correlation coefficient for the relationship between HFT scores and DSBT scores was quite dissimilar with other research findings where coefficients of at least 0.40 were reported (for example, El-Banna, 1987; Al-Naeme, 1991; Bahar, 1999). The low correlation could be due to the difficulty many student teachers faced with the task in disembedding the figures in the HFT irrespective of their working memory status.

6.9.3 The Field Dependency Categories

Based on the distribution of the HFT scores and the formula mentioned in 6.3.3, the student teachers were classified into three groups representing their levels of field dependency. Those who scored 6 points or less were categorised as being field dependent learners while those who scored 11 points or more were categorised as being field independent learners. Others who were not in these two categories were classified as being field neutral (field intermediate) learners. Table 6.13 shows the number of student teachers in each category of field dependency.

Category	No. of student teachers
Field Dependent	104 (35.3%)
Field Neutral	100 (33.9%)
Field Independent	91 (30.8%)

Table 6.13: Categorisation of the student teachers into field dependency categories.

Comparisons between the mean scores obtained by the three categories from both statistics examination and SCG test were made using the one-way between-subjects ANOVA design in each case. *The hypothesis tested was that the mean statistics examination scores for all field dependency categories were equal. Another hypothesis was that the mean SCG test scores for all field dependency categories were equal too.*

The distribution of the mean scores for both the statistics examination and the SCG test is shown in Table 6.14 below.

Field Dependency Categories	Statistics Exam Mean Score & SD	SCG Test Mean Score & SD
Field Dependent	56.6 *(13.7)*	3.4 *(3.4)*
Field Neutral	57.8 *(15.7)*	4.4 *(3.1)*
Field Independent	61.3 *(14.8)*	5.1 *(3.0)*

Table 6.14: The Distribution of the Mean Statistics Examination Scores and Mean SCG Test Scores According to Field Dependency Categories

Although the mean statistics examination score for the field independent category was better than the other two categories and the mean score for the field neutral category was better than the field dependent category, nonetheless, there were no differences in performance between the three categories of field dependency according to the analysis by ANOVA design ($F_{(2, 292)} = 2.571$, df = 2, p = 0.078). One of the reasons could be that the statistics tests and examinations contained items that mainly required the student teachers to use the correct algorithmic procedures to find the solutions. Since these algorithmic procedures were not unfamiliar to most of the student teachers, therefore it was not surprising that the degree of field dependency did not affect their performances in the statistics examination.

For the SCG test, there were, however, significant differences among the mean scores at 1% level ($F = 6.954$, $df = 2$, $p < 0.01$). One of the reasons was obviously the format of the SCG test where the respondents were required to discern the relevant information from the 'noise' in order to pick out the correct answers. This, it was not surprising that the test generally favour the student teachers who were field independent learners.

6.9.4 The Joint Field Dependency and Working Memory Capacity Categories

It would be interesting to see the effect from the combination of the two cognitive factors (working memory capacity and field dependency) on the student teachers' performances in both the statistics examination and the SCG test. For this purpose, the student teachers were subdivided according to their joint working memory capacity and field dependency categories. The number of student teachers in each sub-category is shown in Table 6.15.

	Low WMC	Inter. WMC	High WMC
Field Dependent	33	35	36
Field Neutral	33	33	34
Field Independent	17	37	37

Table 6.15: The distribution of the student teachers into the joint field dependency and working memory capacity categories

The mean scores plus standard deviations (in brackets) from the statistics examination and the SCG test for each joint category are shown in Table 6.16 and Table 6.17 respectively.

	Low WMC	Inter. WMC	High WMC
Field Dependent	**54.9** (*15.6*)	**56.9** (*13.4*)	**58.0** (*12.2*)
Field Neutral	**56.5** (*15.0*)	**57.4** (*16.8*)	**59.5** (*15.7*)
Field Independent	**58.0** (*16.7*)	**61.4** (*14.2*)	**62.8** (*14.6*)

Table 6.16: The distribution of the statistics examination mean scores and standard deviations according to the joint categories

	Low WMC		Inter. WMC		High WMC	
Field Dependent	3.0	*(3.8)*	3.1	*(3.1)*	**4.0**	*(3.3)*
Field Neutral	4.3	*(3.5)*	**4.3**	*(2.7)*	4.7	*(3.2)*
Field Independent	**4.9**	*(2.9)*	5.0	*(3.0)*	5.4	*(3.0)*

Table 6.17: The distribution of the SCG test mean cores and standard deviations according to the joint categories

In each of the tables above, there seems to be an improvement in the mean score obtained in each joint category as one reads across the table from low working memory capacity to high working memory capacity in all field dependency categories. Similarly, the mean score tends to increase from one joint category to another down the table from field dependent to field independent in all working memory capacity categories. The best mean score was obtained by the joint field independent/high working memory capacity category and the worst mean score belonged to the joint field dependent/low working memory capacity category.

The results obtained in this study as shown by the two tables, displayed similar pattern as with many other studies (for example Al-Naeme, 1991; Bahar, 1999; Christou, 2001). However, the pattern observed was not as marked as could be found with the other studies where the mean scores in tests and examinations obtained by the three joint groups; high working memory-field dependent, intermediate working memory-field neutral and low working memory-field independent were almost identical

It was interesting to observe that student teachers with low working memory capacity but who were field independent seemed to have a similar mean score (especially in the statistics examination) when compared with those who had high working memory capacity but who were field dependent. A possible explanation was that the former group had the ability to differentiate the relevant information from the irrelevant ones and thus could use their whole memory space competently while the latter group needed more working memory space to compensate their field dependence characteristics (Johnstone *et al.*, 1993).

Although there seemed to be a pattern where the mean scores for both the statistics examination and the SCG test tended to increase from low working memory capacity group to high working memory capacity group for all field dependency groups and vice versa, the differences between the mean scores in all categories were, however, quite small. Therefore, it is important to see whether the differences among the mean scores were significant. In order to do this, the two-way between subjects ANOVA design is used.

It was observed that there was no main effect of field dependency category on the statistics examination scores ($F_{(2, 286)} = 1.775$, df = 2, p = 0.171). There was also no main effect of working memory capacity category on statistics examination scores ($F_{(2, 286)} = 1.319$, df = 2, p = 0.269). In addition, there was no interaction between the factor of field dependency category and the factor of working memory capacity category ($F_{(4, 286)} = 0.056$, df = 4, p = 0.994).

For the SCG test, it was found that there was a significant main effect of field dependency category on the scores obtained at 1% level ($F_{(2, 286)} = 6.288$, df = 2, $p < 0.01$). This was expected because field independent individuals have the ability to easily discern 'signal' or relevant materials from 'noise' or irrelevant materials in the structural communication grids (Johnstone, 1991). However, there was no main effect of working memory capacity category on the SCG test scores although many of the items mainly required recall of some factual knowledge ($F_{(2, 286)} = 0.491$, df = 2, p = 0.612). The interaction between the factor of field dependency category and working memory capacity category was also not significant ($F_{(4, 286)} = 0.323$, df = 4, df = 4, p = 0.863).

6.9.5 Relationship Between Field Dependency Groups and Attitudes Toward Learning Statistics

It would be interesting to see whether student teachers' degree of field dependency affected their attitudes toward learning statistics. An analysis using the chi-square test (as a test of independence) was made to compare the responses given by student teachers in each field dependency category. The results from this analysis are summarised and shown in Table 6.18 and Table 6.19

Statement	C	Pos.	Neu.	Neg.	χ^2	df	s.l.
I like to study statistics	D	66.3	30.8	2.9	1.5	2	n.s
	N	70.0	27.0	3.0			
	I	61.5	35.2	3.3			
Statistics is difficult to learn	D	24.0	48.1	27.9	1.4	4	n.s.
	N	18.0	53.0	29.0			
	I	18.7	52.7	28.6			
I don't like statistics	D	5.5	19.8	74.7	0.2	2	n.s.
	N	4.0	21.0	75.0			
	I	2.9	20.2	76.9			
Statistics is easier to learn than mathematics	D	20.2	43.3	36.5	2.6	4	n.s.
	N	25.0	44.0	31.0			
	I	17.6	41.8	40.6			
A lot of difficult concepts in statistics	D	48.1	41.3	10.6	6.5	4	n.s.
	N	44.0	36.0	20.0			
	I	46.2	45.1	8.8			
Have to work hard to master statistical concepts	D	85.6	11.5	2.9	2.7	2	n.s.
	N	91.0	7.0	2.0			
	I	92.3	7.7	0.0			
Statistics is a challenging subject	D	84.6	12.5	2.9	1.7	2	n.s.
	N	81.0	17.0	2.0			
	I	87.9	8.8	3.3			
Easier to learn statistics using statistics software	D	35.6	36.5	27.9	5.8	4	n.s.
	N	21.0	44.0	35.0			
	I	26.4	44.0	29.7			

(Legend: C-Category, D-Field dependent, N-Field Neutral, I-Field Independent, df-degrees of freedom, s.l-significant level)

Table 6.18: Student teachers' attitudes toward learning statistics according to field dependency categories (In percentages with N = 295)

Statement	C	Pos.	Neu.	Neg.	χ^2	df	s.l.
Easy - Difficult	D	22.1	52.9	25.0	1.52	4	n.s.
	N	26.0	52.0	22.0			
	I	27.5	53.8	18.7			
Boring lectures – Interesting lectures	D	67.3	21.2	11.5	11.62	4	0.05
	N	45.0	34.0	21.0			
	I	39.6	41.8	18.7			
Heavy workload – Light workload	D	11.5	38.5	50.0	1.07	4	n.s.
	N	10.0	35.0	55.0			
	I	8.8	40.7	50.5			
Tutorials do help – Tutorials don't help	D	46.2	29.8	24.0	5.62	4	n.s.
	N	52.0	23.0	25.0			
	I	42.9	38.5	18.7			
A lot of mathematics Involved – Not mathematical enough	D	39.4	37.5	23.1	5.92	4	n.s.
	N	29.0	46.0	25.0			
	I	24.2	50.5	25.3			
Have to use statistical software – Don't have to use statistical software	D	43.3	42.3	14.4	1.19	4	n.s.
	N	43.0	41.0	16.0			
	I	42.9	37.4	19.8			
Too many tests and quizzes – Too few tests and quizzes	D	25.0	56.7	18.3	5.47	4	n.s.
	N	27.0	58.0	15.0			
	I	14.3	64.8	20.9			

(Legend: C- Category, D- Field dependent, N- Field Neutral, I- Field Independent, df- degrees of freedom, s.l- significant level)

Table 6.19: Student teachers' opinions on the statistics course according to field dependency categories (In percentages with N = 295)

From the analysis, it was found that there was no relationship between the field dependency categories and responses to any of the items regarding student teachers' attitudes toward learning statistics. Regarding their opinions on the introductory statistics course, there was only one item which was significantly associated with the field dependency categories: ' Boring lectures – Interesting lectures' ($\chi^2 = 11.62$, df = 4, $p < 0.05$) which favoured the field dependent student teachers. It seemed that the majority of the field dependent student teachers did not enjoy the statistics lessons where the only teaching strategy employed was the lecture method. Perhaps, they did not enjoy note taking which was the dominant activity in lectures. As Frank (1984) has suggested, field dependent learners did not perform well in lectures due their lack of ability in abstracting and organising information that was presented as part of a larger organised field.

6.10 Conclusions

Some of the major findings from this study were as follows:

1. Student teachers had positive attitudes toward learning statistics. However, this finding should be treated with caution since it was not clear whether they responded to the questions honestly or perhaps it could be due to their own aspiration. Nevertheless, a majority of them believed that statistics was a challenging subject to learn and that they had to work hard to master the statistical concepts.
2. The introductory statistics course's lectures were found to be difficult and uninteresting to some. This might be due to the teaching strategy employed and the content of the course which were deemed to be too mathematical.
3. Male student teachers tended to find statistics as a difficult subject to learn, the introductory statistics course as boring and the contents being too mathematical when compared with their female counterparts.
4. Student teachers from the Non-Mathematics Education programme were more likely to describe the introductory statistics course as being difficult and believed that it would be easier to learn statistics using software packages.
5. In statistics examination, female student teachers performed better than male student teachers in statistics examination while in comparing between programmes of study, Mathematics Education group performed better than

Non-Mathematics Education group. However, there was no interaction between gender and programmes of study on the statistics examination scores.

6. The SCG test revealed that many student teachers did not know fully grasped the ideas about some basic concepts in descriptive statistics and their knowledge about the basic probability rules were also poor despite passing their statistics examination.
7. There was a significantly positive correlation between the statistics examination scores and the SCG test scores but not as high as expected.
8. There were no differences in the performances between gender or between programmes of study in Digit Span Backwards Test (to determine the size of the working memory space) or in Hidden Figures Test (to determine the degree of field dependency).
9. There was a significant correlation between the statistics examination scores and the DSBT scores. This indicated that student teachers with high working memory capacity were likely to perform better than those with low working memory capacity in statistics examination. However, there was no relationship between the statistics examination scores and the HFT scores indicating that the degree of field dependency had no effect on the achievement in statistics examination.
10. As expected, there was a significant relationship between SCG test scores and HFT scores. Student teachers who were field independent were more likely to excel in this type of test due to their better ability in picking out the relevant boxes in order to get the correct responses.
11. There was a significant correlation between the DSBT scores and HFT scores which was consistent with the findings of other research studies.
12. Student teachers who belonged to the field independent/ high working memory capacity category performed the best in both the statistics examination and the SCG test while the worst performers were the student teachers in the field dependent/ low working memory capacity category.
13. Student teachers who were field dependent learners tended to dislike the teaching method used in the introductory statistics course.

CHAPTER SEVEN

RESEARCH STUDY TWO: FIELD EXPERIMENT

7.1 Introduction

Although the majority of the student teachers in the exploratory study appeared to have positive attitudes toward learning statistics, they also found that the introductory statistics course to be quite demanding as well as being dull and uninteresting. Some of the reasons could possibly be due to the way the course was being taught which was mainly through the lecture method and the contents of the course which were quite mathematical, in addition to the emphasis on computational techniques and procedures. Thus, many would resort to learning without understanding by memorising the facts and figures given to them through the lectures so as to avoid failure in the statistics tests and examinations. This seemed to favour those who had high working memory capacity who were likely to excel in the tests and examinations. From the findings in the exploratory study it also appeared that the introductory statistics course put certain groups like the male student teachers, those from the non-mathematics programmes or background, and the field dependent student teachers at a disadvantage.

It was the main aim of this second stage research study to explore whether an alternative teaching strategy to the lecture method that incorporated student-based co-operative learning activities was appropriate for the student teachers in learning statistics especially in the area of probability. Therefore, it was decided to develop some short learning materials or units for this experimental study to be used with some groups of student teachers enrolled in the introductory statistics course. Some of the learning units developed involved practical activities, simulation and related techniques that led to the production, organisation and analysis of the data and the interpretations of results. It was hoped that, through these activities, student discussion could be encouraged and flourish, thinking and interest could be stimulated and greater commitment from the part of the student teachers could be engineered. However, the main objective of the learning units would be to bring about a more positive attitude towards learning statistics in general.

In the following section, the learning units will be described in detail. Then, in the subsequent sections; the experimental design, the study sample and the research instruments are discussed while a summary of the research questions in this study will also be outlined. Finally, the results and analyses as well as the discussions of the study's findings will be presented.

7.2 The Learning Units

The learning units developed for this experimental study were guided by the following criteria suggested by Aliaga & Gunderson (1998) and Byrne (1985):

- The format of the learning units should be interactive. Thus, the learning units should facilitate internalisation of the material presented through maximising the interaction between different student teachers and between student teachers and the learning materials. Thus, small co-operative groups were used.
- The formats and contents of the units should be original as far as possible.
- The learning materials should be seen as relevant to the student teachers and should be derived from the normal introductory statistics course that the student teachers are undertaking.
- The units should be easy to use and the length of time to carry out each of the units should be within the normal class contact time (about one hour).
- The units should be student-based such as to allow for student activity which is independent of lecturer involvement. The lecturer should adopt a facilitating role to help in the smooth running of the learning process.

A total of five learning units were developed based on the topics of probability, normal distribution and correlation. It should be pointed out that not all the contents of the units were original. Some ideas were derived from introductory statistics textbooks, such as those authored by Freund & Perles (1999) and Aliaga & Gunderson (1998), while others were based on personal experiences of the researcher. The language used in the learning units was the Malay Language since the introductory statistics was conducted in that language in the colleges where this study was carried out.

Each of the units was pre-trialled with a group of final year student teachers from Sultan Idris Education University in Malaysia under the supervision of a mathematics education lecturer. The main purposes of the preliminary trial were to check for ambiguities and to make sure the learning units were comprehensible and capable of being completed within the allocated period of one hour each. As a result of the pre-trial, the learning units were modified slightly. The titles and brief descriptions of the learning units that were ultimately used in the experiment are listed below while the full complete versions can be found in Appendices F,G,H.I and J.

- 'Does colour matter?' – An introduction to probability using the relative frequency approach. This approach applies to situations that can be thought of as being repeatable under similar conditions. In this learning unit a situation is given where marbles of various colours are randomly selected from a bag a large number of times. The student teachers are asked to predict the colour of the marbles that are likely to be picked. They will also carry out a simple activity of flipping coins many times over.
- 'The three doors' – This is an adaptation of a problem called Monty's Dilemma suggested by Aliaga & Gunderson (1998). Student teachers are introduced to the simulation method to estimate probability of an event by using a game with many repetitions. In this game, the student teachers will determine which of the two strategies will give them the best chance to win a coveted prize. They will work in pairs to simulate 20 outcomes of the game for each strategy and then estimate the probability of winning in each case.
- 'Who is likely to win' – This learning unit is about the relationship between probability and betting odds. As an introduction, student teachers are given odds for the outcomes of a soccer match and are then asked to predict the most likely outcome based on the odds given. Then, they are shown how to translate odds into probabilities.
- 'Can midterm test scores predict final exam scores?' – This unit is about the relationship between two variables: midterm scores and final exam scores from an introductory linear algebra course. Student teachers are asked to find out whether there exists a relationship between the two variables. They are also introduced to a particular graphical display of the relationship between the two variables, namely the scatterplot. They are then asked to comment on the overall pattern in the scatterplot based on direction, form and strength. The idea of correlation is also introduced as a measure of how strong the relationship is between the two variables.
- 'Who is the best student' – The idea of the normal distribution phenomenon is introduced. Also, the concept of standardised score is explained. In this learning unit

examination scores for a class of 34 students in six subjects are given. The task for the student teachers are to find the best approach to selecting the top three students based on the examination scores.

7.3 Experimental Design

The main aim of this second stage of the research study was to investigate the effects the learning units had on student teachers' attitudes toward learning statistics; more importantly, the way they liked to learn statistics. For this purpose, a quasi-experimental design was adopted. According to Campbell & Stanley (cited in Robson, 1994), a quasi-experiment is a research design using an experimental approach but where random assignment to treatment and comparison group has not been used. For several reasons such as administrative problems and the constraint of time, it was not possible to randomly assign student teachers that were enrolled in the introductory statistics courses to treatment and comparison groups. Thus, a 'pre-test post-test non-equivalent groups' quasi-experimental design (Robson, 1994) was seen as appropriate for this study. The design is illustrated in Figure 7.1 below.

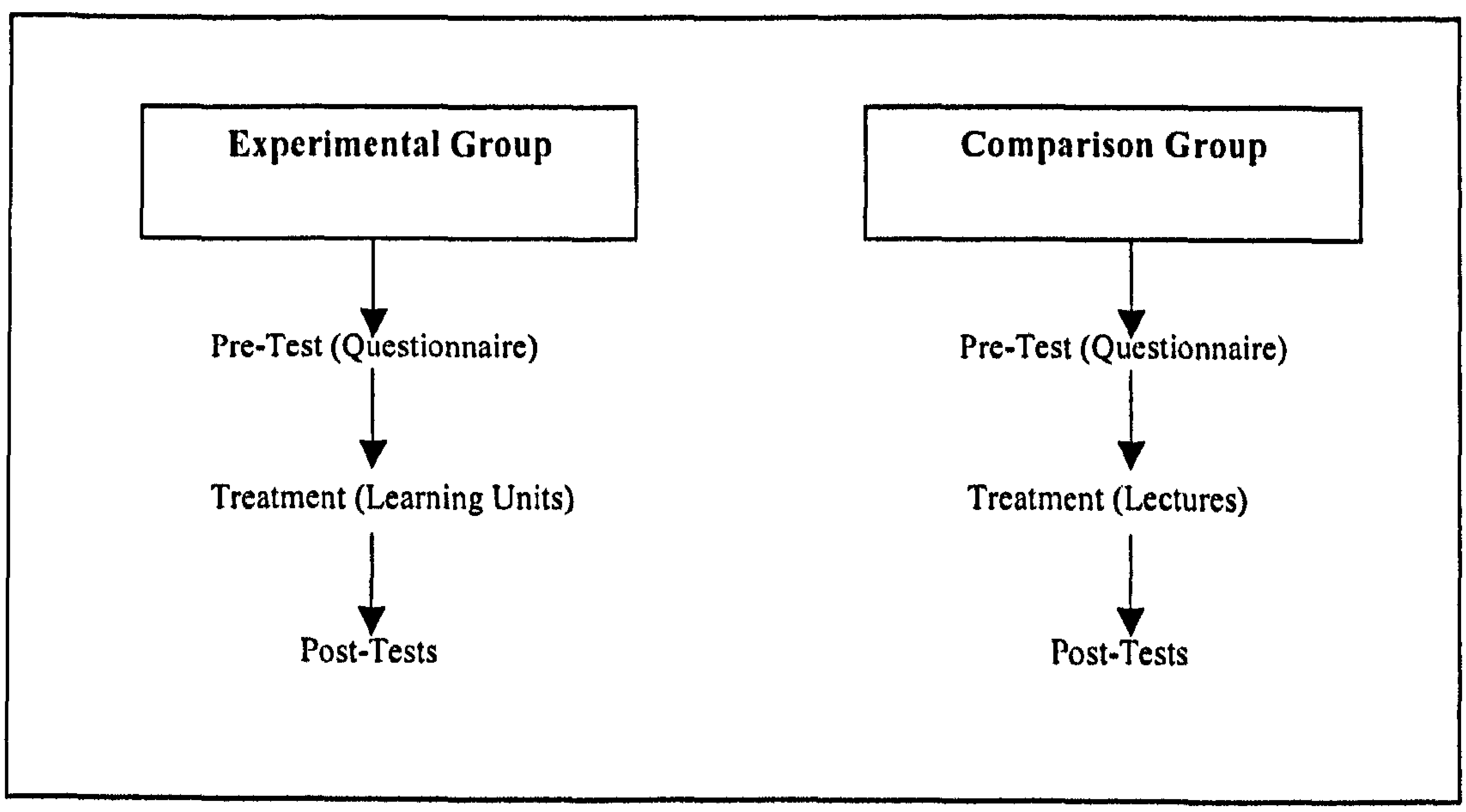


Figure 7.1: The pre-test post-test non-equivalent groups design

For both the experimental and comparison groups, questionnaires were given to survey their attitudes toward learning statistics. Basically, the main purpose was to find out whether or not the two groups differed before treatment. For the treatment, learning units were given to the experimental group while the comparison group received none of them. However, it was decided that it would be fair and appropriate if both groups received the same cognitive input. Thus, the contents of the learning units were delivered to the comparison group through the normal lecture method. As mentioned earlier, the learning units were student-based and the student teachers carried out all the activities by themselves through small co-operative groups (in pairs or at most three student teachers to a group) and also independent of the lecturer's involvement. Finally, post-tests consisting of a questionnaire and a structural communication grid (SCG) test were given to both groups. These research instruments are discussed in detail in Section 7.5

7.4 The Study Sample

In this experiment, the participants were student teachers from three teacher training colleges as well as from Sultan Idris Education University (SIEU) who were enrolled in the introductory statistics courses. The three colleges were chosen because they also conducted some of the Bachelor of Education (B.Ed) courses offered by SIEU. As far as the introductory statistics course was concerned, the contents of the syllabus and the methods of assessment in these colleges were similar to the one that could be found at SIEU. Two introductory statistics classes from each college were selected by the college lecturers themselves. One class was assigned as the experimental group while the other class was assigned as the comparison group. SIEU provided two classes as experimental group and one class as a comparison group.

The breakdown of the student teachers participating in this experiment according to colleges and groups is given in Table 7.1

Colleges	Experimental Group	Comparison Group	Total
Sultan Idris Education University	204	103	307
Ipoh Teacher Training College	61	58	119
Technical Teacher Training College	50	54	104
Raja Melewar Teacher Training College	55	60	115
Total	370	275	645

Table 7.1The breakdown of student teachers participating in the experiment

A combined total of 645 student teachers (370-experimental group and 275-comparison group) from four teacher training colleges including Sultan Idris Education University, took part in this experimental study. The distributions of the student teachers according to gender and programmes of study for both the experimental and comparison groups are shown in Table 7.2 and Table 7.3.

Experimental Group	Male	Female	Total
Mathematics Education	68	227	295
Non-Mathematics Education	33	42	75
Total	101	269	370

Table 7.2: The breakdown of student teachers participating in the study (experimental group)

Comparison Group	Male	Female	Total
Mathematics Education	45	172	217
Non-Mathematics Education	12	46	58
Total	57	218	275

Table 7.3: The breakdown of student teachers participating in the study (comparison group)

As can be seen from the tables, the female student teachers and the Mathematics Education group dominated the enrolment in the introductory statistics courses. The greater number of female student teachers was not surprising since it reflected the overall composition ratio of 3 to 1 (75% females and 25% males) in any teacher training college in Malaysia. Most of the participants in this experiment were either in their second or third semester of the Bachelor of Education programme.

7.5 The Study Instruments

The study instruments used in this field experiment were the pre-test (questionnaire) and the post-tests (questionnaire and the SCG test) mentioned in the experimental design. In addition, it was also decided to measure the student teachers' degree of field dependency (the hidden figures test) and their working memory space capacity (the digit span backwards task). The pre-test questionnaire, the post-test questionnaire and the SCG test will be discussed in turn. The discussions on the digit span backwards task and the hidden figures test can be found in sections 6.3.3 and 6.3.4 respectively. All the study instruments were in the Malay Language.

7.5.1 Pre-Test and Post-Test Questionnaires

Both the experimental and comparison groups were given the same pre-questionnaire that contained items that covered the following areas: personal information, attitudes toward learning statistics and opinions about their introductory statistics course (see Appendix K for the complete questionnaire). The items in the pre-questionnaire were almost identical to the items in the exploratory study's questionnaire. To assess the attitudes toward learning statistics, the Likert method was used. The Osgood's semantic differential method was used to assess the participants' opinions on the statistics courses. Responses to each item concerning the attitudes and opinions were analysed separately.

Two sets of post-questionnaire were developed; one set for the experimental group and the other set for the comparison group. The items for both sets were the same except for some additional questions included in the set for the experimental group to find out their opinions regarding the learning units they were experiencing. The common items for both sets of questionnaire required student teachers to provide their personal information and their opinions about the ways they would like to learn statistics. The latter were assessed using the Osgood's semantic differential method. The complete questionnaires can be found in Appendices L and M. Responses to each item concerning the attitudes and opinions were also analysed separately.

Face validity was used to measure the extent to which items in both questionnaires measured what they were designed to measure. This was achieved by using the expert opinions of a couple of mathematics education lecturers in Malaysia who also helped in piloting the questionnaires and the SCG test (see section 7.5.2) with their own students.

It was initially planned to conduct semi-structured interviews with some student teachers from the experimental group to get feedback and opinions about the learning units that they had experienced. This plan was, however, aborted due to shortage of time and difficulty in accessing the student teachers individually. Instead, items relating to the learning units were included in the post-questionnaire intended for the experimental group.

7.5.2 Structural Communication Grid (SCG) Test

The general discussions on SCG are given in section 6.3.5. For this study, only one set of SCG was devised and contained only nine items (see Appendix N). The items in the SCG were based on the learning units and the parallel lecture materials given to the experimental groups and the comparison groups respectively. The SCG test was pre-trialled with a group of final year student teachers (mathematics education) at Sultan Idris Education University who had already taken the introductory statistics course earlier. As a result of the pre-trial, sources of confusion and ambiguities were spotted and rectified.

The scoring system used in this SCG test was relatively straightforward. Since all but two questions had just one possible answer each, a score of 1 was given to the correct answer while an incorrect answer or no answer would be given a score of zero. Each of the other two questions had two possible answers. A respondent got a score of 2 if both answers were given correctly. A score of 1 was given if just one answer was given correctly or a combination of one correct and one wrong answer were given. Other combinations or no answer were given a score of zero.

7.6 The Data Collection Procedures

Permission was sought from each college through the respective statistics lecturers to have access to the introductory statistics classes. The lecturers also decided which classes would take part and be assigned as experimental group or comparison group, as well as the timetable for the field experiment to be conducted at their respective colleges. Overall, this part of the study was carried out within a period of six weeks. The schedule for this experimental study is shown in Table 7.4.

Dates	Planned Activities
02.12.02 – 06.12.02	Visit the colleges to arrange dates for the field experiment
09.12.02 – 13.12.02	Visit colleges to hand out the pre-questionnaire and carry out the field experiment involving the experimental and comparison groups
16.12.02 – 20.12.02	Continue conducting the field experiment
23.12.02 – 27.12.02	Semester break
30.12.02 – 03.01.03	Continue conducting the field experiment
06.01.03 – 10.01.03	Continue conducting the field experiment
13.01.03 – 17.01.03	Carry out the assessments: post-questionnaire and SCG test

Table 7.4: A schedule of activities for the experimental study

Each experimental group and each comparison group had five sessions (about one hour each) of the learning units and lectures respectively. Pre-questionnaire was given prior to the beginning of the field experiment while the post-questionnaire and SCG test were given a week after the end of the field experiment.

Due to time constraint, it was decided to postpone the hidden figures test (HFT) and the digit span backwards test (DSBT) to a later date when the researcher made another trip to Malaysia. This finally happened in the first week of August 2003. However, the researcher only managed to get hold of about 62% of the original participants in the experimental group (228 out of 370) and about 59% in the comparison group (164 out of 275). The distributions of those who took part at this stage of the experimental study are given in Tables 7.5 and 7.6 respectively.

Experimental Group	Male	Female	Total
Mathematics Education	48	158	206
Non-Mathematics Education	17	5	22
Total	65	163	228

Table 7.5: The breakdown of the student teachers who sat for the HFT (experimental group)

Comparison Group	Male	Female	Total
Mathematics Education	43	121	164
Non-Mathematics Education	0	0	0
Total	43	121	164

Table 7.6: The breakdown of the student teachers who sta for the HFT (comparison group)

Again due to the time factor, the remaining participants only managed to take part in the hidden figures test (HFT) to determine their degree of field dependency. Thus, the intention to measure the size of the working memory space of the student teachers in this study was not realised. It was also decided to obtain the introductory statistics' final examination scores (second semester, 2002/2003) from the lecturers in August 2003.

7.7 The Research Questions

In this study, the experimental group was exposed to the five learning units which emphasised student teachers working cooperatively in small groups while the comparison group was given the same materials based on the learning units but delivered through the lecture method. Thus, it would be interesting to investigate the difference in performances exhibited by the respective groups and also between the genders and programmes of study within the groups. Therefore, from this investigation, it was hoped that several questions pertaining to the way student teachers in both groups learnt statistics could be answered. These questions are as follows:

- Was there any difference between the experimental group and the comparison group relating to attitudes toward learning statistics and opinions on the introductory statistics course?
- Were there any differences between the genders and also between the Mathematics Education and Non-Mathematics Education in each of the experimental and comparison groups concerning the attitudes toward learning statistics and opinions on the introductory statistics course?
- Did the student teachers in each group differ in the opinions given on how they would like to learn statistics best?
- What were the views of the student teachers in the experimental group concerning the learning units that they had experienced?
- Was there any difference in performance between the experimental and comparison groups in the structural communication grid test?
- Did the degree of field dependency relate to student teachers' performances in structural communication grid test and the statistics examination?
- Was there a relationship between the field dependency categories and the responses given to the items concerning attitudes toward learning statistics, opinions on the introductory statistics course and opinions on how they would like to learn statistics best?

7.8 Results and Discussions from the Pre-Questionnaire Survey

The two main sections in the pre-questionnaire were concerned with student teachers' attitudes toward learning statistics and their opinions on the introductory statistics courses. The opinions of both experimental and control groups on these two areas were examined by investigating the differences in their performances.

To analyse the differences in the performances between the two groups, the chi-square (χ^2) test was used. It was decided to use the chi-square test (test for homogeneity) instead of the chi-square goodness-of-fit test. The latter is used to determine whether the observed frequencies differed significantly from the theoretically expected frequencies. Thus, the goodness-of-fit test was not considered appropriate because there was no reason to assume that the results of one of the groups represented expected frequencies. The chi-square test for homogeneity evaluates whether or not the two groups are homogeneous with respect to the proportion of observations in each of the five categories in the assessment of attitudes and opinions (Sheskin, 2000).

The chi-square statistic was calculated using sets of five cells because five-point scales were used in both Likert method and Osgood's semantic differential method. However, for clarity and also due to the constraint governing the use of the chi-square test, it was found that combination to produce three cells was frequently necessary. Thus, for items using the Likert method, cells representing 'strongly agree' and 'agree' were combined to represent the opinion 'agree' while the cells representing 'strongly disagree' and 'disagree' were combined to represent the opinion 'disagree'. For items using the semantic differential method (like the example shown below), the first two cells on the left were combined to represent the opinion 'Exciting' and the last two cells on the right were combined to represent the opinion 'Dull'. The middle cell was to represent the neutral opinion.

Exciting	←				→	Dull

The frequencies of responses to these items were expressed in the form of percentages and these are shown in Table 7.7. However, the chi-square tests were performed on the raw data. In these tables, responses from the experimental group (N = 370) and comparison (N = 275) group were put next to each other after each statement so as to compare the differences that might exist between the two groups before the experiment was conducted.

The main conclusion that could be drawn from the Table 7.7 is that statistically significant differences between the experimental and comparison groups did not occur for any item concerning the attitudes toward learning statistics. A more detailed examination of the results above shows that just over a half of student teachers in both groups liked to study statistics (E = 52%; C = 56%) and very few student teachers confessed to dislike statistics (E = 7%; C = 5%). An overwhelming majority in both groups believed that 'Statistics is a useful tool in everyday life'. A slight majority in both groups placed the statements 'Statistics is difficult to learn' and 'Statistics is easier than other branches of mathematics' at the midway points or the neutral positions. About a third of all participants agreed that they did not enjoy the statistics courses that they were enrolled into and just over 40% felt confident about coping with the statistics courses. More than two thirds of all the student teachers believed that it would be easier to learn statistics using statistical software packages.

Statement	G	SA	A	N	D	SD	χ^2	Df	s.l
I like to study statistics	E	8.9	43.2	44.1	2.7	1.1	1.3	2	n.s.
	C	13.8	41.8	41.8	2.5	0.0			
Statistics is difficult to learn	E	1.4	24.3	54.9	17.0	2.4	3.6	2	n.s.
	C	4.0	23.6	58.5	13.5	0.4			
Statistics is a useful tool in everyday life	E	24.6	58.3	15.5	1.4	0.3	0.1	2	n.s.
	C	28.7	53.1	17.5	0.7	0.0			
I don't like statistics	E	1.9	5.1	28.4	48.1	16.5	0.8	2	n.s.
	C	0.0	5.5	27.6	45.4	21.5			
Statistics is easier than other branches of mathematics	E	1.4	13.8	50.3	31.6	3.0	2.3	2	n.s.
	C	4.0	14.2	52.4	28.8	0.7			
A lot of difficult concepts in Statistics	E	3.5	37.6	43.5	14.9	0.5	0.3	2	n.s.
	C	3.3	37.1	42.5	15.6	1.5			
Statistics is a challenging subject	E	15.7	58.6	23.5	2.2	0.0	1.9	2	n.s.
	C	10.5	61.8	23.6	4.0	0.0			
I don't enjoy the statistics course that I'm currently studying	E	6.8	27.8	44.1	18.9	2.4	3.2	2	n.s.
	C	7.6	31.6	37.1	23.3	0.4			
It would be easier to learn statistics using software packages	E	20.8	48.6	24.9	4.9	0.8	0.6	2	n.s.
	C	11.6	55.3	27.6	5.1	0.4			
I feel confident about coping with my statistics course	E	5.4	35.4	46.8	10.8	1.6	2.8	2	n.s.
	C	9.5	36.0	45.8	8.0	0.7			

LEGEND:
G-Group E-Experimental C-Comparison SA-Strongly Agree A-Agree N-Neutral
D-Disagree SD-Strongly Disagree df-degree of freedom s.l-significant level

(Responses expressed in %, N(Experimental) = 370, N(Comparison) = 275)

Table 7.7: Student teachers' attitudes toward learning statistics

In general, student teachers' attitudes toward learning statistics were positive although they believed that learning statistics was a challenging task. However, it must be pointed out that it was not clear whether the responses given by the student teachers concerning the attitudes were honest or simply indicating their own aspiration. It is also observed that the pattern of responses from both groups with regard to this questionnaire is very similar to the pattern of responses in the exploratory study's questionnaire (see table 6.4 in section 6.5).

Word & Statement Pairs	G						χ^2	df	s.l
Easy/Difficult	E	3.2	26.8	55.7	13.2	1.1	4.1	2	n.s.
	C	2.2	23.6	54.2	17.1	2.9			
Boring lectures/Interesting lectures	E	5.9	26.2	42.2	17.8	7.8	2.2	2	n.s.
	C	9.1	27.6	36.7	20.7	5.8			
Heavy workload/Light workload	E	5.1	27.3	43.8	18.9	4.9	1.3	2	n.s.
	C	2.5	25.8	45.5	23.6	2.5			
Course too mathematical/	E	5.4	29.2	48.9	15.4	1.1	3.1	2	n.s.
Course less mathematical	C	4.0	36.0	47.6	11.6	0.7			
Too many tests and quizzes/	E	1.4	15.4	54.1	24.6	4.6	2.5	2	n.s.
Too few tests and quizzes	C	1.1	11.6	54.2	28.7	4.4			
Real life data rarely used in examples/	E	14.6	43.0	28.1	12.2	2.2	7.1	2	0.05
Real life data always used in examples	C	17.1	43.5	31.8	6.9	0.7			
Too many tedious calculations/	E	5.9	55.9	21.9	14.6	1.6	0.4	2	n.s.
Not many calculations involved	C	8.0	55.6	21.5	13.8	1.1			
Software packages are used in class/	E	3.8	14.1	19.5	43.5	19.2	4.5	2	n.s.
Software packages are not used	C	4.7	18.9	14.9	42.2	19.3			
Interpretations of statistical results are	E	2.2	8.1	20.5	55.9	13.2	1.8	2	n.s.
emphasised/Little emphasis is given	C	2.2	10.5	21.8	48.0	17.5			
The lecturer shows how statistics is	E	5.7	15.4	34.1	31.9	13.0	3.9	2	n.s.
used in daily life/The lecturer does not	C	4.4	11.3	33.1	36.0	15.3			
show how statistics is used in daily life									

LEGEND:
G-Group E-Experimental C-Comparison df-degree of freedom s.l-significant level

(Responses expressed in %, N(Experimental) = 370, N(Comparison) = 275)

Table 7.8 Student teachers' opinions on the introductory statistics course

From Table 7.8, it is clear that once again statistically significant differences between the experimental and control groups did not exist for all but one item regarding the opinions about their introductory statistics courses. The exception was on the response to the item 'Real life data rarely used in examples/Real life data always used in examples' where the difference was significant at 5% level (χ^2 = 7.1, df = 2, p < 0.05). A higher proportion of student teachers in the experimental group (14.4% compared to 7.6% for the comparison group) believed that the lecturers always used real data when statistical examples were given. It was quite difficult to explain the reason behind this difference because in each of the colleges, only one lecturer was involved in teaching the introductory statistics course. Perhaps the student teachers themselves could not distinguish the difference between real data (obtained empirically and through research reports etc.) and artificial data (made up by the lecturers).

A scrutiny of the responses given reveals that more than half of the student teachers thought that the introductory statistics course was neither easy nor difficult (E = 56%; C = 54%). Opinions were divided on the items 'Heavy workload/Light workload' and 'Boring lectures/Interesting lectures'. However, about a third of all student teachers regarded the statistics lectures as boring. Similarly, more than a third of the student teachers in both groups believed that the introductory statistics course was too mathematical in the contents (E = 35%; C = 40%) and only a few of them found the course to be less mathematical to their liking (E = 16%; C = 12%). The majority of them also felt that most statistics lessons involved mainly the computational aspects of statistics (E = 62%; C = 64%) and less emphasis was given to the meaning and interpretation of the numbers underlying the statistical results obtained from the computations (E = 69%; C = 66%). About half expressed dissatisfaction that their lecturers did not really show how statistics could be used in daily life (E = 45%; E = 51%). More than 60% of the student teachers in both groups complained that statistical software packages were not used in the teaching of statistics while the rest either agreed that the packages were in fact used in the classrooms (E = 18%; C = 24%) or gave a neutral response (E = 19%; C = 15%). It was found out later that only one lecturer from one particular college regularly used the packages such as 'SPSS' and 'Minitab' in his classrooms. Although every college has computer laboratories with statistical packages installed into the machines, most lecturers did not take full advantage of the facilities available. Perhaps, most of the lecturers did not have enough time to complement the statistics lectures with the usage of the packages in the classrooms due to pressure to complete the syllabus on time.

In general, student teachers opinions about their introductory statistics course were slightly less than positive. The pattern of responses in most of these items is quite similar to the one expressed by the student teachers in the exploratory study (see

Table 6.6 in section 6.5) and, therefore, lending support to the belief that the introductory statistics course that was offered to the student teachers was really dull and uninteresting as well as demanding in its content.

7.8.1 Comparison by Gender

The comparison between the responses given by the male and female student teachers in each group on their attitudes toward learning statistics and their opinions on the introductory statistics course were investigated using the chi-square test (test for homogeneity). The complete results are given in Appendix S. A summary of the results for each of the experimental and comparison groups are given below:

Experimental group

- There were no significant relationships between gender and the responses to the items concerning attitudes toward learning statistics except for the item 'Statistics is difficult to learn' which favoured the male student teachers (χ^2 = 6.9, df = 2, $p < 0.05$). In addition, it was observed that a much lower proportion of the male student teachers felt confident about coping with the statistics course as they did with other courses (Male – 33%, Female – 44%). However, a higher percentage of the male student teachers believed that it would be easier to learn statistics by using the software packages (Male – 71%, Female – 64%).
- There were significant relationships between gender and the responses to only two of the items relating to the opinions about the introductory statistics course which are as follows:

a) 'Easy – Difficult' (χ^2 =10.15, df = 2, $p < 0.01$) – A higher percentage (20.8%) of the male student teachers found the course difficult compared to only 10.8% among the female student teachers.

b) 'Boring lectures – Interesting lectures' (χ^2 =15.91, df = 2, $p < 0.01$) – Again, a higher proportion of the male student teachers found the introductory statistics' lectures to be boring rather interesting.

Comparison group

- There were no significant relationships between gender and the responses to any of the items concerning attitudes toward learning statistics. However, a higher percentage of the male student teachers agreed with the statement 'A lot of difficult concepts in statistics' (Male – 40%, Female – 29%) while a higher percentage of the female student teachers agreed with the statement 'I feel as confident about coping with my statistics course as I do about other courses' (Male – 48%, Female – 68%)

- There were no significant relationships between gender and the responses to any of the items concerning opinions about the introductory statistics course. Despite this, it was found that a higher proportion of the male student teachers than their female counterparts agreed that the statistics course was too mathematical (Male – 42%, Female – 33%) and that the lectures were boring (Male – 40%, Female – 25%)

In both groups, the male student teachers tended to believe that that statistics is difficult to learn with a lot of difficult concepts. They were also more likely to view the introductory statistics course as being difficult with boring lectures as well as not feeling confident about coping with the course when compared with their female counterparts. This was consistent with the views and opinions expressed by another group of male student teachers in the exploratory study. The reason why a higher proportion of male student teachers displayed these negative attitudes than the female student teachers could be due to their academic backgrounds. Generally, the female student teachers were more qualified academically than the male student teachers. In order to attract more male students into the teaching profession, SIEU normally lowers the admission criteria for them. Thus, it was not surprising that the male student teachers found the introductory statistics course quite difficult to follow or that their attainments in statistics tests and examinations were generally lower than their female counterparts.

7.8.2 Comparison by Programmes of Study

The comparison between the responses given by the Mathematics Education (ME) and the Non-Mathematics Education student teachers in each group on their attitudes toward learning statistics and their opinions on the introductory statistics course were investigated using the chi-square test (test for homogeneity). The complete results are given in Appendix T. A summary of the results for each of the experimental and comparison groups are given below:

Experimental group

- There were no statistically significant differences in the responses given to any of the items concerning the attitudes toward learning statistics by the respective programmes of study. However, the percentages of the NME student teachers who agreed with the following items were much higher or much lower than the ME student teachers (with difference of more than 5%):
  1. 'Statistics is difficult to learn' (NME – 28%, ME – 17%).
  2. 'Statistics is a challenging subject' (NME – 76%, ME – 69%).
  3. 'It would be easier to study statistics using statistical software packages (NME – 73%, ME – 66%).
  4. 'I enjoy the statistics course that I am currently studying' (NME – 34%. NME – 41%).
- There was only one item relating to the opinions about the introductory statistics course where the difference to the responses given was statistically significant: 'Course too mathematical – Course not mathematical enough' ($\chi^2 = 16.7$, df = 2, $p < 0.001$). A significantly higher percentage of the NME student teachers believed that the course was too mathematical (NME – 39%, ME – 16%). It was also observed that a higher percentage of the NME student teachers believed that the introductory statistics course was difficult with boring lectures and too many tedious calculations.

Comparison group

- There were no statistically significant differences in the responses given to any of the items concerning attitudes toward learning statistics by the respective programmes of study. However, it was found that a much higher proportion of ME student teachers liked to study statistics and believed that learning statistics was easier than learning other mathematical subjects. On the other hand, a higher proportion of NME student teachers believed that it would be easier to learn statistics with the aid of statistical software packages.
- There were only two items relating to the opinions about the introductory statistics course where the differences to the responses given were statistically significant:

a) 'Course too mathematical / Course not mathematical enough' ($\chi^2 = 7.2$, df = 2, $p < 0.05$). A significantly higher percentage of the NME student teachers believed that the course was too mathematical (NME – 30%, ME – 21%).

b) 'The lecturer shows very little of how statistics can be used in daily life / The lecturer shows how statistics is used in everyday life a lot' ($\chi^2 = 9.2$, df = 2, $p < 0.05$). A significantly higher percentage of the NME student teachers believed that the lecturer did not show how statistical knowledge could be applied in everyday life (NME – 69%, ME – 47%)

As in the experimental group, it was also observed that a much higher proportion of the NME student teachers found the statistics lectures to be boring (NME – 48%, ME – 34%), too many tedious calculations involved (NME – 66%, ME – 55%), the lecturer rarely used real life data in examples (NME – 78%, ME – 69%) and also gave little emphasis to the interpretations of the statistical results obtained from the calculations (NME – 76%, ME – 63%).

In both groups, a higher proportion of the NME student teachers than the ME student teachers viewed statistics as a difficult and a challenging subject to learn and that the introductory statistics course was too mathematical with the lectures delivered in an uninteresting manner. Furthermore, the NME student teachers also believed that learning of statistics would be easier with the aid of the statistical software packages. The majority of them also would like the lecturer to show them how the statistical knowledge could be applied in everyday life. Again, the views and opinions expressed by the NME student teachers were almost similar to the group of NME student teachers in the exploratory study. The negative attitudes toward the introductory statistics course were not unexpected since, to most of the student teachers, the course was seen as an unpleasant requirement of their Bachelor of Education degree programme.

7.9 Results and Discussions from the Post-Questionnaire Survey

As mentioned in 7.5.1, the main section in the post-questionnaires given to both experimental and control groups was exactly the same and consisted of ten items that used the Likert method's five-point scale designed to assess the student teachers' opinions on how they would like to learn statistics best. The frequencies of responses, expressed in percentages, for both the experimental and comparison groups are shown in Table 7.9.

As with the pre-questionnaire, the chi-square (χ^2) test was used to compare the results from the experimental group with those obtained by the comparison group. Since the observed frequencies were obtained under two different conditions and it was the intention of this study to see whether any differences that might occur between the two groups were statistically significant, the chi-square test was used as a test of differences between independent groups.

From Table 7.9, it is evident that there were statistically significant differences to the opinions given on the following statements:

a) 'Need to have discussions between lecturer/students and student/student' (χ^2 = 37.9, df = 2, $p < 0.001$) – strongly favoured by the experimental group.
b) 'The learning should be interactive and the lecturer's role is just as a facilitator' (χ^2 = 10.8, df = 2, $p < 0.01$) – strongly favoured by the experimental group.
c) 'Students should be taught how to use statistics effectively to make decisions in real life situations' (χ^2 = 5.9, df = 2, $p < 0.05$) – favoured by the experimental group.
d) 'Just have to memorise the facts and figures given by the lecturer' (χ^2 = 11.1, df = 2, $p < 0.01$) – strongly disagreed by the experimental group.
e) 'I do not need to understand the statistical concepts and interpretations to pass the course' (χ^2 = 24.1, df = 2, $p < 0.001$) – strongly disagreed by the experimental group.

A much higher proportion of the student teachers in the experimental group than in the comparison group agreed with each of the statements a), b) and c). Similarly, more student teachers in the experimental group than in the comparison group disagreed with the statements d) and e). Perhaps, the significant differences in the responses given to these five statements could be attributed to the positive experience of learning statistics offered by the learning units where activities were carried out in groups co-operatively. Thus, the student teachers in the experimental group could see

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
The lecturer gives all the input and the students take down the notes without question	E	3.0	10.5	21.9	61.4	3.2	5.5	2	n.s.
	C	2.5	17.1	23.6	52.4	4.4			
Need to have discussions between lecturer/students and student/student	E	35.4	55.4	9.2	0.0	0.0	37.9	2	0.001
	C	27.6	44.7	26.5	0.7	0.4			
Just have to memorise the fact and figures given by the lecturer	E	0.3	6.2	16.5	67.8	9.2	11.1	2	0.01
	C	0.4	12.4	21.1	53.8	12.4			
Do not need to do practical work in the Classroom	E	1.1	2.2	11.4	70.3	15.1	4.2	2	n.s.
	C	2.2	2.5	16.0	60.0	19.3			
The learning should be interactive and the lecturer's role is just as a facilitator	E	21.1	60.0	17.8	1.1	0.0	10.8	2	0.01
	C	20.4	50.9	21.8	6.9	0.0			
Need to use the software packages to avoid the tedious calculations and doing the graphs/charts	E	16.2	47.8	28.1	7.6	0.3	1.4	2	n.s.
	C	15.3	50.5	28.7	5.5	0.0			
The lecturer should use real life data in Examples	E	9.5	38.4	44.6	7.0	0.5	2.0	2	n.s.
	C	9.1	38.2	42.2	10.2	0.4			
I do not need to understand the concepts and interpretations to pass the statistics course	E	0.3	4.0	10.0	59.2	26.5	24.1	2	0.01
	C	0.4	3.6	24.4	46.9	24.7			
Students should be taught how to use statistics effectively to make decisions in real life situations	E	19.7	62.7	16.5	1.1	0.0	5.9	2	0.05
	C	13.8	60.7	23.6	1.5	0.4			
Tests and exam questions should focus more on the calculations rather than interpretations	E	16.2	43.5	34.3	4.9	1.1	3.5	2	n.s.
	C	11.3	47.3	31.6	8.4	1.5			

LEGEND:
G-Group E-Experimental C-Comparison SA-Strongly Agree A-Agree N-Neutral
D-Disagree SD-Strongly Disagree df-degree of freedom s.l-significant level

(Responses expressed in %, N(Experimental) = 370, N(Comparison) = 275)

Table 7.9: Student teachers ' opinions on how they would like to learn statistics best

the benefits of learning statistics through this method where discussions among group members were frequent and encouraged. In addition, discussion sessions with the facilitator were also held after the completion of each unit. Nevertheless, it should be pointed out that even with the comparison group where the lecture method alone was employed, the majority of the student teachers seemed to favour learning statistics where discussions prevailed and group work done co-operatively and they should be taught on how to use statistics effectively in everyday situations. Most of the student teachers in the comparison group also agreed that there was more to learning statistics than just memorising facts and figures and that they needed to understand statistical concepts and interpretations in order to succeed in the statistics course.

The other five items in Table 7.9 did not produce statistically significant differences between the groups although the general pattern of responses from the experimental group did appear to be slightly more favourable. A detailed look at the results shows that the majority of student teachers in both groups did not prefer to have the lecturer to give them all the input and restricted their role to that of note-takers (E = 64.6%, C = 56.8%). Similarly, most student teachers believed that they needed to carry out practical activities in the statistics classroom and not merely listen and take down notes during lectures (E = 85.3%, C = 79.3%). Just under half of them felt that their lecturer should use real life data when giving statistical examples (E = 47.9%, C = 47.3%). Almost two thirds of the respondents in both groups pointed out the need to use statistical software packages so as to make redundant the tedious calculations and messy drawings of the graphs and charts (E = 64.1%, C = 65.8%). However, almost 60% of all student teachers in this study preferred to maintain the status quo of the tests and examination format where the questions and items were mainly computational-based. Perhaps they were more confident to deal with objective type computational-based questions rather than questions which required them to interpret or to explain statistical concepts and problems which were more subjective in nature.

In the post-questionnaire for the experimental group, there were a couple of questions that required student teachers to express their opinions on the learning units. In the first of these questions, they were asked, '*What are your general opinions about the learning units that you have had experienced recently?*'. About 90% (338 out of 375) of the student teachers responded to this question and gave a wide range of responses. Generally, the responses were favourable toward the learning units. Some of the favourable comments are as follows:

- They were interesting and enjoyable.

- New style of teaching and learning.
- The learning units looked simple, easy to follow and well designed.
- I liked the group activities where students co-operated with each other to solve problems.
- The lecturer did not interfere with our group activities.
- I could express my opinions freely.
- The discussions with the other group members helped me a lot.
- When you discussed and tackled the problems together with your partner or group members, the more you would learn and remember.
- I liked it when other group members listened to what I had to say.
- The end of the session's discussion with the lecturer was informative and helped me to understand the learning units better.
- It made the learning of statistics livelier
- We did not have to take down notes as we normally did during the lectures.
- The learning units helped me to understand more about probability
- The learning units made me realised that learning statistics was not all boring and pointless.
- The learning units encouraged hands-on exploration of statistical concepts like in probability.
- The learning units allowed students to take an active part in the learning process.
- The format of the learning units was in a logical order where students were introduced with problems ranging from easy to difficult and finally arriving to a conclusion.
- With the learning units, I actually did do some statistical activities like collecting and analysing data as well as discussing results with other members of my group.
- Helped me to overcome some misconceptions about statistics and probability.
- Some of the contents in the units were related to everyday life situations.
- Encouraged higher order thinking whereby students analysed and interpreted the data collected and the information given.

Only about 4% (12 out of 338) gave unfavourable responses about the learning units. Some of the negative opinions expressed are as follows:

- I found discussions boring.
- Did not enjoy working in groups.
- Some of the questions seemed to have no definite answers.

- I prefer all the materials given to me through the lectures.
- The learning units would not help me to pass the statistics course.
- The learning units were a waste of time.

In the second question, student teachers were asked the following question: *'Do you think it is a good idea to introduce similar learning units into the introductory statistics course? Please explain the reason for your answer.'* As with the first question, almost 90% (330 out of 375) of the student teachers in the experimental group responded. An overwhelming majority of over 95% of those who responded agreed with the question asked. Some of the reasons given are as follows:

- It would make the statistics course interesting and livelier.
- Doing things together with other students is much better than simply listening to the lectures and taking down notes.
- It would encourage group work and inculcate good values such as tolerance, respecting each other opinions and work co-operatively.
- With the learning units, I need to discuss things over with my partner or other members of the group and these discussions help me to be alert most of the time and also help to stimulate my mind.
- Improve attitudes toward learning statistics especially to students like us who are not good in mathematics.
- Help to develop and enhance our higher order thinking skills such as in analysing and in evaluation.
- Help us to be engaged in this subject called statistics.
- Having these units would show that statistics is full of ideas and not a dull subject with mere numbers and calculations.
- It would make me more informed user of information that I encounter everyday.
- Although the lecturer would still be present, the statistics course would now be more student-based and the students themselves would be responsible for their own learning.

Those who opposed the idea to incorporate similar learning units into the introductory statistics course cited reasons that were quite similar to the negative opinions expressed about the learning units in the first question. Some simply did not like the idea of working in a group while others mentioned their concern about tests and examination. The latter felt that through lecture method, they were more confident about what to expect in tests and examination.

In general, the learning units were well received by the student teachers in the experimental group. A vast majority of the student teachers liked to learn statistics where the environment would allow them to be active learners. They liked learning statistics interactively and co-operatively, holding discussions with their partners or members of their groups as well as carrying out practical activities that involved games and problem solving. They also would like to use the statistical software packages to help them in learning statistics efficiently. Most of them did not like the idea of memorising the facts and figures from the notes they took down via the lectures. It is interesting to note that these opinions on how student teachers in the experimental group would like to learn statistics best were also shared by their counterparts in the comparison group albeit to a lesser extent.

7.9.1 Comparison by Gender

The comparison between the responses given by the male and female student teachers in each group about their opinions on how they would like to learn the introductory statistics course were investigated using the chi-square test of homogeneity. The complete results are given in Appendix U. A summary of the results for each of the experimental and comparison groups is given below:

Experimental group

- There were no significant relationships between gender and the responses given to all the items except 'The lecturer should use real life data in examples' ($\chi^2 = 9.3$, df = 2, $p < 0.05$) which favoured the male student teachers.
- It was observed that a higher proportion of the male student teachers agreed that 'Need to have discussions between lecturer/students and between student/student' (Male – 96%, Female – 89%), 'Need to use software packages to avoid tedious calculations and doing the graphs/charts' (Male – 72%, Female – 64%). On the other hand, a higher proportion of the male student teachers disagreed that 'The lecturer gives all the input and the students take down the notes without question' (Male – 70%, Female – 62%)

and 'Just have to memorise the facts and figures given by the lecturer' (Male – 80%, Female – 68%).

Comparison group

- There were no significant relationships between gender and the responses given to any of the items. Nevertheless, a higher proportion of the male student teachers than the female student teachers agreed with the statements 'Need to have discussions between lecturer/students and between student/student' (Male – 74%, Female – 67%) and 'Students should be taught how to use statistics effectively to make decisions in real life situations' (Male – 84%, Female – 72%).

It is interesting to note that a higher percentage of the male than the female student teachers in both the experimental and comparison groups favoured having discussions whether between the lecturer and the students, as well as between the students themselves in the statistics classroom. Perhaps, this was to be expected since the results from the pre-questionnaire revealed that the male student teachers generally appeared to dislike the way the statistics course was taught. It was also observed that a vast majority of the male student teachers tended to disagree that they learned statistics passively. Most of the male student teachers (and to a lesser degree, the female student teachers) preferred to learn statistics actively where they would participate in discussions and group activities as well as being able to apply the statistics they learned in real life situations.

7.9.2 Comparison by Programmes of Study

The complete results from the comparison of the responses given by the Mathematics Education (ME) and Non-Mathematics Education (NME) student teachers on how they would like to learn statistics best are given in Appendix V. A summary of the results for each of the experimental and comparison group are given below:

Experimental group

- There was only one item 'Students should be taught how to use statistics effectively to make decisions in real life situations' ($\chi^2 = 6.2$, $df = 2$, $p < 0.05$)

that showed significant relationship at 5% level which favoured the NME student teachers.

- Other notable differences although not significant were, 'The lecturer gives all the input and the students take down the notes without question' (which favoured the ME student teachers), 'The lecturer should use real life data in examples' (which favoured the NME student teachers) and 'The teaching should be interactive and the lecturer's role is just as a facilitator' (which favoured the NME student teachers).

Comparison group

- There were no significant relationships between the programmes of study and the responses given to any of the items.
- Some notable differences although not significant occurred in the items 'The lecturer gives all the input and the students take down the notes without questions (which favoured the ME student teachers) and 'The teaching should be interactive and the lecturer's role is just as the facilitator' (which favoured the NME student teachers).

Although there were no significant differences concerning the responses given to most of the items about how they would like to learn statistics by the two groups (ME and NME), the NME student teachers were more likely to favour learning statistics actively and how to apply the statistical knowledge they had acquired in everyday life. Perhaps, coming from a lesser mathematical background, the NME student teachers preferred that the introductory statistics course not to be dominated by algorithmic techniques but instead should focus on acquiring and understanding the statistical concepts meaningfully and then be able to apply them to novel situations. Nevertheless, it must be pointed out that to a lesser extent, the ME student teachers also favoured the kind of learning that promoted the acquisition of the statistical knowledge actively and meaningfully.

7.10 Analysis of the Results from the SCG Test

The facility values for all items in the SCG test from each of the experimental and comparison groups are given in Table 7.10. The facility value (FV) is the proportion of respondents answering an item correctly. For the complete SCG test and the correct answers, please refer to Appendix..

	Facility Value (FV)								
	Item1	Item2	Item3	Item4	Item5	Item6	Item7	Item8	Item9
Experimental (N=370)	0.56	0.12	0.13	0.36	0.32	0.18	0.61	0.29	0.81
Comparison (N=275)	0.41	0.09	0.08	0.13	0.20	0.13	0.51	0.11	0.79

Table 7.10: The facility values for all items in the SCG test

From Table 7.10, it can be seen clearly that the experimental group performed consistently better than the comparison group in every item of the SCG test. However, the performances for both groups were less than satisfactory except for Items 7 and 9. The performances for both groups in every item will now be discussed in turn. The SCG is given below.

1 0	2 1.0	3 0.20
4 0.17	5 - 0.67	6 0.67
7 0.88	8 0.50	9 - 0.42

Item 1
A boy tosses a fair die a number of times. Each time, he records the face up of the die whether it is 1,2,3,4,5 or 6. What is the relative frequency for '6' that he would expect if he tosses the die 1 000 times?
Answer: Box 4 (0.17)

This item is based on the frequency interpretation of probability. The facility values for this item are 0.56 and 0.41 respectively for the experimental and comparison groups. The performances were a bit disappointing considering the fact that the question was relatively straightforward. Some popular incorrect responses were Box 7 and Box 2.

Item 2
Ali obtained 60 % in his mathematics examination. The mathematics teacher told the class that the average mark was 65 %. If the teacher were to convert all the marks into standard scores based on the standard normal distribution, what could be the possible standard score for Ali?
Answer: Either Box 5 (– 0.67) or Box 9 (– 0.42)

Although the answer to this item seemed obvious since the score obtained was below the average (mean) mark, an overwhelming majority of student teachers in both groups did not get either of the answers correctly ($FV_{(experimental)} = 0.12$; $FV_{(comparison)} = 0.09$). The popular wrong answers were Box 3 and Box 7. It appeared that the student teachers had a misunderstanding of what a standard score meant.

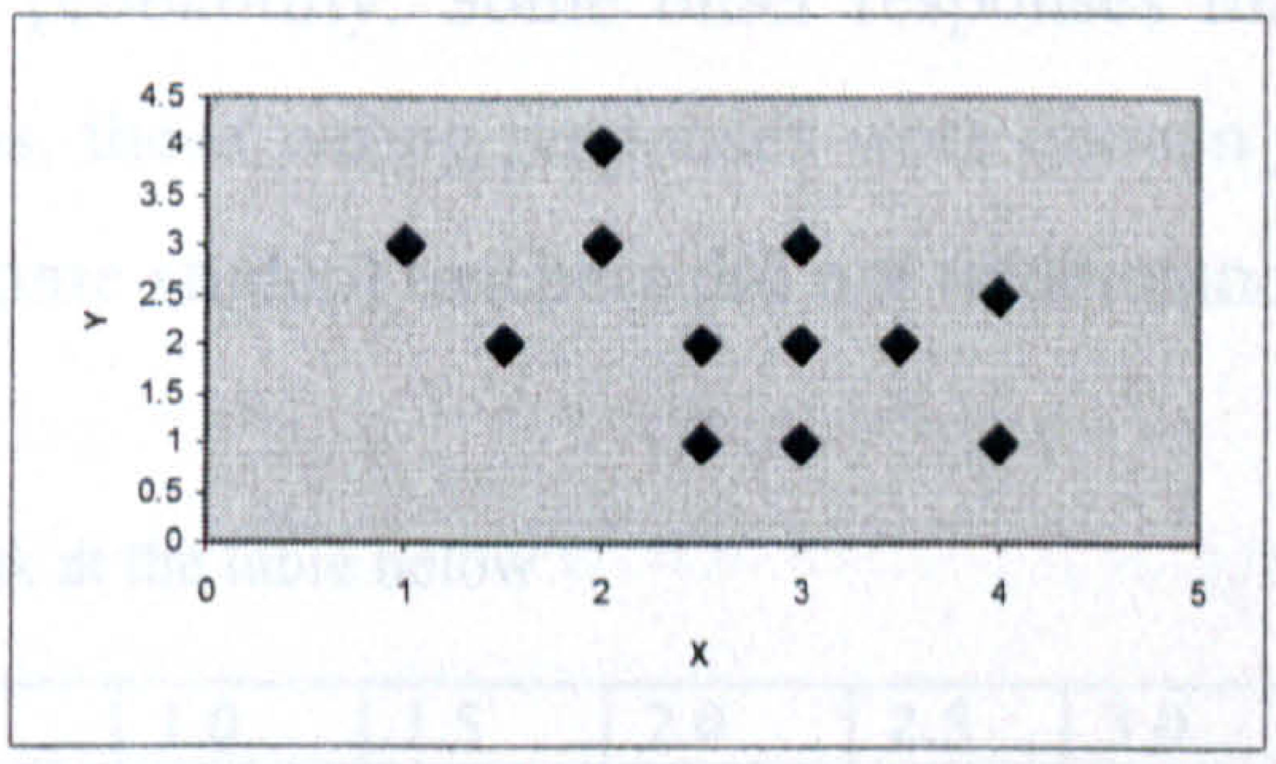
Item 3
A couple plans to have children. They would like to have a boy to be able to pass on the family name. After some discussion, they decide to continue to have children until they have a boy or until they have 3 children, whichever comes first. What is the probability that they will have a boy among their children?
Answer: Box 7 (0.88)

The poor performances from this item ($FV_{(experimental)} = 0.13$; $FV_{(comparison)} = 0.08$) were expected because the student teachers needed to do a bit of calculation using some of the basic rules of formal probability theory or estimated the probability using the simulation method (which could be tedious!). The most popular wrong answer for both groups was Box 8. Possibly, they based their incorrect response on a single outcome; whether a boy or a girl instead of three possible outcomes; a boy (the first child) or a girl (the first child) and a boy (the second child) or two girls (the first two children) and a boy (the third child).

Item 4
Manchester United FC is quoted by a leading bookmaker to have odds of 5 to 1 against winning this season European Champions' League Trophy. What is the probability of Manchester United FC of winning the Trophy?
Answer: Box 4 (0.17)

The performances for this item were generally quite poor ($FV_{(experimental)} = 0.36$; $FV_{(comparison)} = 0.13$). The most popular answer was Box 3 (probably they assumed that 5 to 1 against is equal to 1 over 5). A majority of the student teachers appeared to have misconception about the idea of 'odds' and how they are related to probabilities.

Item 5
Look at the scatterplot below.



Values of X are plotted against the values of Y. There seems to be a relationship between X and Y. What could be the possible value for the correlation coefficient r (the value indicating the strength of the relationship) between X and Y?
Answer: Either Box 5 (– 0.67) or Box 9 (– 0.42)

Both groups performed satisfactorily for this item ($FV_{(experimental)} = 0.72$; $FV_{(comparison)} = 0.60$). The majority of the student teachers appeared to realise the negative relationship between the two variables although some were unsure about the strength of the relationship. However, it was a mystery why the others (28% from the experimental group and 40% from the comparison group) chose positive coefficients for the correlation between the two variables.

Item 6
A schoolgirl tosses three fair coins simultaneously. She repeats the activity 100 times. Each time, she records the face up of each of the coins whether it is 'head' or 'tail'. Estimate the relative frequency for obtaining at least a 'head' among the three pieces of coins.
Answer : Box 7 (0.88)

Item 6 is quite similar to item 3. However, the performances of both groups were slightly better in Item 6 than in Item 3 ($FV_{(experimental)} = 0.18$; $FV_{(comparison)} = 0.13$). Perhaps the student teachers were more used to deal with the activity of tossing coins rather than deciding on family planning! Actually, this item contains no element of stopping after a certain outcome which is what complicates item 3. As with item 3, the most popular incorrect response was Box 8

Item 7
Malaysia plays Indonesia in a semi final match of the Tiger Cup competition on 27 December 2002 in Jakarta. Based on previous records, it is estimated that the probability that Malaysia to win is 0.18 and for Indonesia to win is 0.32. After 90 minutes, what is the probability that the match would be drawn ?
Answer: Box 8 (0.50)

Both groups performed quite satisfactorily in this item ($FV_{(experimental)} = 0.61$; $FV_{(comparison)} = 0.51$). This item required a minor calculation involving some of the basic rules of probability. Some other responses that were chosen were Box 4 and Box 6. Perhaps, these wrong responses were chosen purely by guessing, which might indicate that some student teachers did not understand the basic rules of probability.

Item 8
Please look at the table below

T	1.0	1.5	2.0	2.5	3.0	3.5
F(t)	2.2	3.3	4.4	5.5	6.6	7.7

Without making any calculation, what is the correlation coefficient for the strength of the association between **F(t)** and **t**

Answer: Box 2 (1.0)

This item required the student teachers to estimate the coefficient between the two variables. From the figures in table, it was obvious that the relationship between *F(t)* and *t* was positively perfect and linear. However, the performances from both groups in this item were disappointingly low ($FV_{(experimental)} = 0.29$; $FV_{(comparison)} = 0.11$). It seems that most of the student teachers could not figure out exactly the value of the coefficient by just looking at the figures from the table. Perhaps they needed to plot the values against each other on a graph to see the relationship more clearly. Two of the most popular incorrect responses were Box 6 and Box 7

Item 9
Malaysia is a tropical country. What is the probability that Kuala Lumpur would be covered in snow on 14 February 2003 ?
Answer: Box 1 (0)

This proved to be the easiest of the items and the high facility values were expected ($FV_{(experimental)} = 0.81$; $FV_{(comparison)} = 0.79$). Among the popular incorrect answers were Box 5 and Box 9. Apparently, those who gave these answers thought impossible events should have probability with negative values.

The total scores obtained from the SCG test for each individual in both groups were recorded and the distributions of the scores are shown in Figure 7.1.

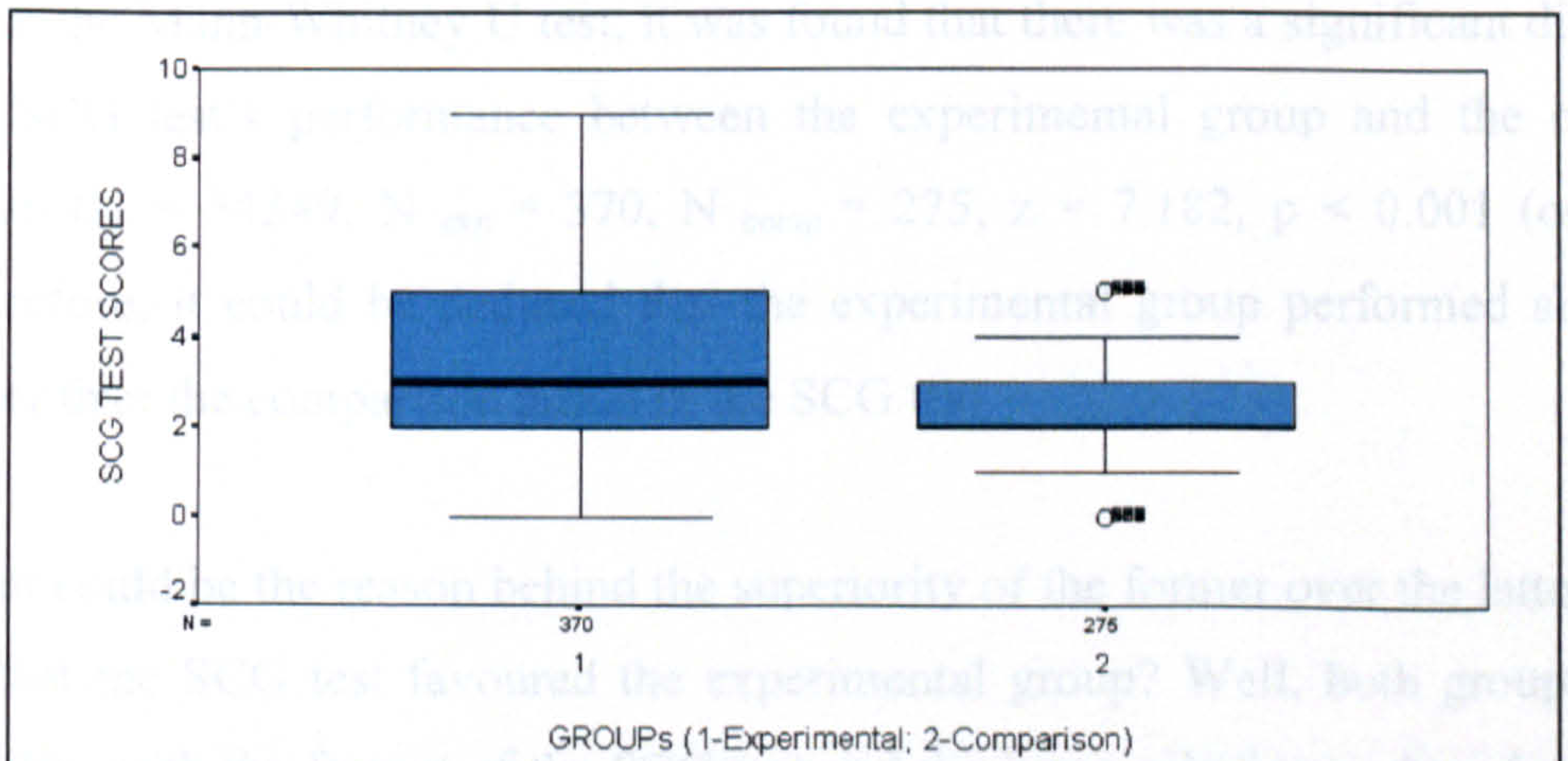


Figure 7.2: The distributions of the SCG test scores (experimental and comparison groups) (NB: O^{xxx} indicates outliers)

The descriptive statistics for the SCG test scores' distributions for both groups are given in Table 7.11.

	Min	Max	Median	1st Q	2nd Q	Mean	S.D.
Experimental Group (N = 370)	0	9	3	2	5	3.5	1.8
Comparison Group (N = 275)	0	5	2	2	3	2.5	1.3

Table 7.11: Descriptive statistics for the SCG test scores' distributions

In both groups, the distributions were slightly skewed positively (with outliers present in the comparison group) indicating that the SCG test was quite difficult for the student teachers. However, the distribution of the SCG test scores for the experimental group was very much more spread-out than the distribution for the comparison group. It is also obvious from the box plots and the descriptive statistics that the student teachers in the experimental group performed much better than the student teachers in the comparison group. Nevertheless, to test whether the difference in performance was significant or not, the Mann-Whitney U test was used. *The hypothesis tested was that the experiment group would perform better than the comparison group in the SCG test.* The t-test was not used because the score variances of the two groups did not meet an equality of variance test. According to Sheskin (2000), the sampling distribution for the Mann-Whitney U test is not as affected by violation of the homogeneity of variance assumption as is the sampling distribution for the t-test.

From the Mann-Whitney U test, it was found that there was a significant difference in the SCG test's performance between the experimental group and the comparison group ($U = 34349$, $N_{exp} = 370$, $N_{comp} = 275$, $z = 7.182$, $p < 0.001$ (one-tailed)). Therefore, it could be deduced that the experimental group performed significantly better than the comparison group in the SCG test.

What could be the reason behind the superiority of the former over the latter? Could it be that the SCG test favoured the experimental group? Well, both groups were not familiar with the format of the SCG test and the items asked were based on the same materials that were covered in both the learning units and the lectures. Thus, it would be fairly certain that the SCG test did not favour one group over the other. It might be that most student teachers in the comparison group, where the lecture method was employed, had forgotten all the facts and figures from the notes that they had copied down. Since the student teachers in both groups were not informed that they were going to be assessed a week after the end of the experimental study, perhaps no effort were being made to study the materials given to them either with the learning units or with the lecture notes. However, the learning units which were student-centred and put emphasis on group activities and discussions might have helped the student teachers in the experimental group to remember more what they had learned and experienced. It must also be pointed out that the experimental group also took down notes but based on the discussions between the student teachers themselves and also from the points summarised by the lecturer at the end of the learning units sessions. Perhaps, it can be argued that the learning units, being a novelty, possibly made the student teachers to appreciate more the learning of statistics that was engaging and enjoyable. Thus, it could be assumed that the learning units had positive effects on some of the student teachers in the experimental group where they had possibly learned with understanding that had also promoted remembering.

7.10.1 Comparison by Gender

In each group, comparisons were also made between the male and female student teachers regarding their performances in the SCG test. The descriptive measures are given in Table 7.12.

	Min	Max	Median	1st Q	2nd Q	Mean	S.D.
Experimental Group:							
Male (N = 101)	0	9	4	2	5	3.8	1.9
Female (N = 269)	0	8	3	2	5	3.4	1.8
Comparison Group:							
Male (N = 57)	0	5	2	2	4	2.4	1.4
Female (N = 218)	0	5	2	2	3	2.6	1.3

Table 7.12: Descriptive statistics for the SCG test scores' distributions (comparison by gender)

In the experimental group, the male student teachers seemed to perform better than their female counterparts in the SCG test while in the comparison group, the female student teachers performed slightly better. To test whether the differences in performances were significant, statistical analysis using t-tests were carried out. For the experimental group, the following statistics were obtained: $t = 1.81$, $df = 368$, $p =$

0.072. Thus, it can be concluded that there was no difference in performance between the male and female student teachers in the SCG test. For the comparison group, the statistics obtained were as follows: t = 1.01, df = 273, p = 0.315. Similarly, the result shows that there was no difference in performance between the genders in the test.

It is interesting to note that the mean score obtained by the male student teachers in the experimental group was higher than their female counterparts although it had been revealed previously from the pre-questionnaire (see section 7.8) that the male student teachers found that the introductory statistics quite difficult, their attainments in statistics tests and examinations were generally lower than the female student teachers. Perhaps, it can be argued that the learning units that they experienced had positive effects in their learning of statistics like improving their attitudes, and thus they produced a slightly better performance than their female counterparts.

7.10.2 Comparison by Programmes of Study

In each group, comparisons were also made between the Mathematics Education (ME) and the Non-Mathematics Education (NME) student teachers regarding their performances in the SCG test. The descriptive measures are given in Table 7.

	Min	Max	Median	1st Q	2nd Q	Mean	S.D.
Experimental Group:							
ME (N = 295)	0	9	3	2	5	3.6	1.8
NME (N = 75)	0	7	3	2	5	3.2	1.8
Comparison Group:							
ME (N = 217)	0	7	2	2	3.5	2.5	1.3
NME (N = 58)	0	5	2	2	3	2.4	1.3

Table 7.13: Descriptive statistics for the SCG test scores' distribution (comparison by programmes of study)

In both groups, the ME student teachers performed slightly better than the NME student teachers judging by the mean scores obtained. Nevertheless, to determine whether the difference in the mean scores obtained was statistically significant or otherwise, the independent t-test was performed in both cases. For the experimental group, the following statistics were acquired: t = 2.07, df = 368, $p < 0.05$. Thus, it can be concluded that there was a significant difference (at 5% level) in the performance achieved by the ME and the NME student teachers that favoured the former. For the comparison group, the following statistics were obtained: t = 0.61, df = 273, p = 0.545. It appeared that there was no significant difference in the performance shown by both groups of student teachers.

7.11 Analysis of the Statistics Examination Scores

As with the exploratory study (see section 6.6), the statistics examination scores were derived from the class quizzes, the mid-term test and the final examination. The final examination paper can be found in Appendix O and the format as well as the contents was quite similar to the final examination paper obtained for the exploratory study. The distributions of the statistics examination scores for both the experimental and comparison groups are shown in Figure 7.3.

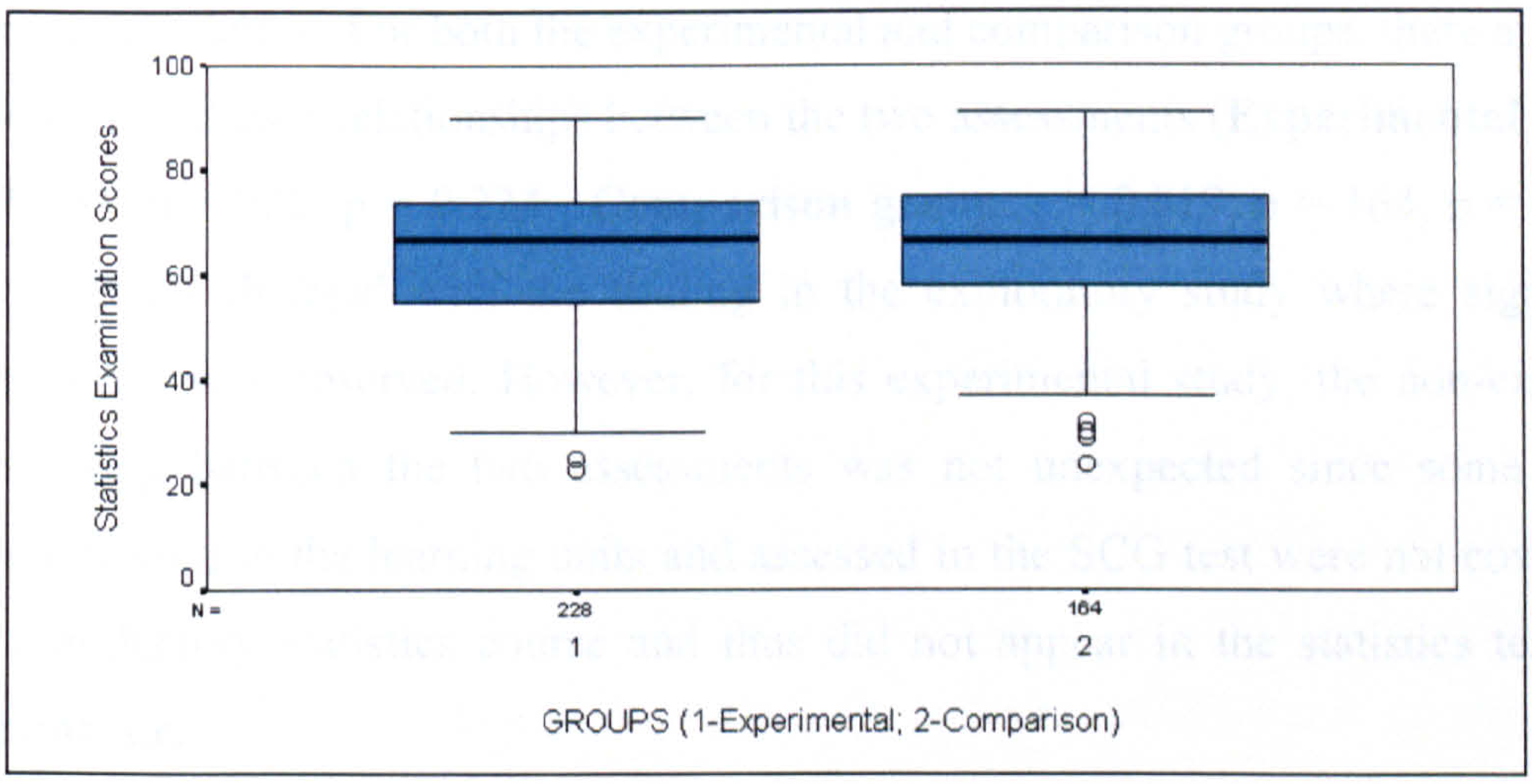


Figure 7.3: The distribution of the statistics examination scores (NB: O indicates outlier)

The distributions of the statistics examination scores was slightly more spread out and negatively skewed for the experimental group than for the comparison group. From the data shown in Table 7.13, it can be seen that all the descriptive measures for both groups were almost identical. The table also shows that the majority of student teachers performed quite well in the statistics course's assessments where the emphasis was on routine computational exercises.

	Min	Max	Median	1st Q	2nd Q	Mean	S.D.
Experimental Group	23	90	67	55	74	64.7	13.4
Comparison Group	24	91	67	58	75	65.2	13.6

Table 7.14: Descriptive statistics for the statistics examination scores' distribution

To test whether the performances between the two groups were different or otherwise, an independent t-test was employed. It turned out that there was no difference between the mean scores obtained by both groups ($t = 0.390$, $df = 390$, $p = 0.697$). This result was not surprising since the learning units were of 5 hours of work out of a total course lasting 50 hours. Therefore, it was unlikely that such a small curriculum input would make an observable difference to the final performance.

A correlational analysis to measure the strength of the linear association between the statistics examination scores and the SCG test scores was performed using the Pearson correlation. For both the experimental and comparison groups, there appeared to be no significant relationships between the two assessments (**Experimental group**: $r = 0.081$, $n = 228$, $p = 0.224$; **Comparison group**: $r = 0.019$, $n = 164$, $p = 0.809$). These results differed with the finding in the exploratory study where significant relationship was observed. However, for this experimental study, the non-existence relationship between the two assessments was not unexpected since some of the materials used in the learning units and assessed in the SCG test were not covered in the introductory statistics course and thus did not appear in the statistics tests and examination.

7.11.1 Comparison by Gender

In each group, comparisons were also made between the male and female student teachers regarding their performances in the statistics examination. The descriptive measures are given in Table 7.15.

	Min	Max	Median	1^{st} Q	2^{nd} Q	Mean	S.D.
Experimental Group:							
Male (N = 65)	23	90	57	47	67	58.6	14.2
Female (N = 163)	25	90	69	62	76	67.1	12.2
Comparison Group:							
Male (N = 43)	24	85	63	47	73	59.9	16.4
Female (N = 121)	30	91	68	59	75	66.8	12.0

Table 7.15: Descriptive statistics for the statistics examination scores' distribution (comparison by gender)

As can be seen from the table, it was evident that female student teachers in both groups outperformed their male counterparts in the statistics examination. To confirm these observations, the independent t-test for the experimental group and the Mann-Whitney U test for the comparison group were used. The latter test was used because the variances of the statistics examination scores for the males and females in the comparison group did not satisfy the equality of variance test. *The hypothesis tested was that there was no difference between the female student teachers' performance in the statistics examination and the male student teachers' performance.* The tests did indicate that female student teachers performed better than the male student teachers in the statistics examination (**Experimental:** $t = -4.51$, $df = 226$, $p < 0.001$; **Comparison:** $U = 1947.5$, $N_{Male} = 43$, $N_{Female} = 121$, $z = 2.446$, $p < 0.05$). This relationship between gender and statistics examination scores also confirmed the earlier finding in the exploratory study. The superior performance of the female student teachers over their male counterparts in the statistics examination was not surprising considering the fact that their overall academic backgrounds were also better than the male student teachers. In addition, it could also be argued that their attitudes toward the introductory statistics course were slightly more positive than their male counterparts.

An inter group comparison between the same genders in each group was also carried out. There was no difference in performance between the male student teachers in the experimental group and their counterparts in the comparison group ($t = -0.398$, $df = 106$, p 0.691). Similarly, the same conclusion was arrived with the female student teachers ($t = -0.030$, $df = 282$, $p = 0.976$).

7.12 Results and Discussions from the Hidden Figures Test

The distributions of the HFT scores for both groups are shown in Figure 7.4 and the descriptive statistics are described in Table 7.16.

	Min	Max	Median	1st Q	2nd Q	Mean	S.D.
Experimental Group	0	17	8	6	10	8.1	3.1
Comparison Group	1	19	8	6	11	8.6	3.6

Table 7.16: Descriptive statistics of the HFT scores' distribution

From Figure 7.4, the distribution of the HFT scores for the experimental group seems to be normally distributed (if the outliers are discounted) while for the comparison group, the distribution looks slightly skewed to the right and also shows greater variability. Apart from the shape of the distributions, the descriptive statistics gave almost identical measures.

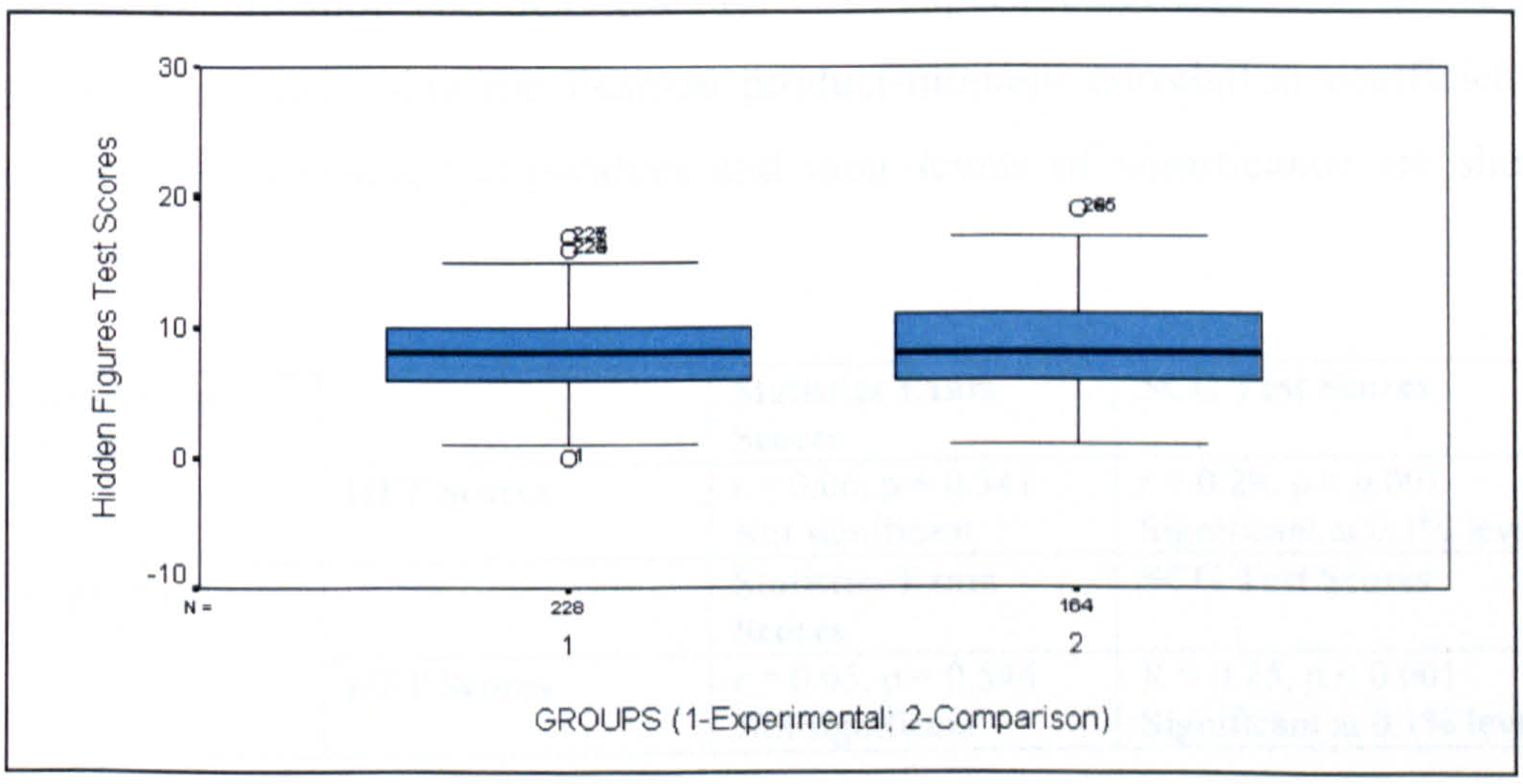


Figure 7.4: The distribution of the HFT scores (NB: O indicates outlier)

Using the Mann-Whitney test (instead of the independent t-test because of inequality of variances) the following hypothesis was tested: *There was no difference observed between the mean score obtained by the experimental and the comparison groups in the HFT*. Indeed, this was found to be the case with the outcome of the test seemed to support the hypothesis stated (U = 17280, N_{exp} = 228, N_{comp} = 164, z = 1.286, p = 0.198 (two-tailed)). It can be concluded that the HFT did not favour either group.

Thus, one could find student teachers with varying degrees of field dependency in both groups.

The t-test was used to study the effect of gender on the HFT scores in both groups. Results indicated that there were no differences between the genders concerning their performances in the HFT (Experimental group : $t = -0.522$, $df = 226$, $p = 0.602$; Comparison group : $t = -0.739$, $df = 162$, $p = 0.739$). The correlational analysis using the point biserial coefficient also suggested the absence of significant relationship between HFT scores and gender (Experimental group : $r_{pb} = -0.057$, $n = 228$, $p = 0.391$, two-tailed ; Comparison group : $r_{pb} = -0.048$, $n = 164$, $p = 0.544$, two-tailed). These results also confirmed the finding in the exploratory study where it was found that the HFT did not discriminate between the genders.

The degree of relationship between the HFT scores, which would determine an individual's degree of field dependency, and each of the other assessment scores (statistics examination and SCG test) for both experimental and comparison groups was also measured using the Pearson product-moment correlation coefficient. The correlation coefficients, the p-values and their levels of significance are shown in Table 7.17

Experimental (N = 228)		**Statistics Exam Scores**	**SCG Test Scores**
	HFT Scores	r = 0.06, p = 0.341 Not significant	r = 0.29, p < 0.001 Significant at 0.1% level
Comparison (N = 164)		**Statistics Exam Scores**	**SCG Test Scores**
	HFT Scores	r = 0.05, p = 0.544 Not significant	R = 0.25, p < 0.001 Significant at 0.1% level

Table 7.17: Correlation between HFT scores and other assessments' scores

As expected, there were significant correlations between the HFT scores and the SCG test scores in both groups supposedly due to the nature of the SCG test where one needed to distinguish the 'relevant' from the 'irrelevant' in order to choose the correct responses. As with the exploratory study, there was no significant relationship between the HFT scores and the statistics examination scores in either of the groups.

Based on the distributions of the HFT scores and the formula mentioned in section 6.3.3, the student teachers in both experimental and comparison groups were classified into three categories representing their levels of field dependency. The classification process for both groups was similar to the one for the exploratory study (see section 6.9.3). The Tables 7.18 and 7.19 show the classification of the student teachers into field dependency categories.

Category (for Experimental Group)	Number of Student Teacher
Field Dependent	75 (32.9%)
Field Neutral	88 (38.6%)
Field Independent	65 (28.5%)

Table 7.18: Classification of student teachers into field dependency categories (experimental group)

Category (for Comparison Group)	Number of Student Teacher
Field Dependent	62 (37.8%)
Field Neutral	57 (34.8%)
Field Independent	45 (27.4%)

Table 7.19: Classification of student teachers into field dependency categories (comparison group)

Comparisons between the mean scores obtained by the three categories from both the statistics examination and the SCG test were carried out using the one-way between-subjects ANOVA design in each case. The following hypotheses were tested:

- The mean statistics examination scores for all field dependency categories in the experimental group were all equal.
- The mean statistics examination scores for all field dependency categories in the comparison group were all equal.
- The mean SCG test scores for all field dependency categories in the experimental group were all equal.
- The mean SCG test scores for all field dependency categories in the comparison group were all equal.

The distributions of the mean scores (with standard deviations in brackets) for both the statistics examination and the SCG test are shown in Tables 7.20 and 7.21.

Field Dependency Categories (Experimental Group)	**Statistics Exam Mean Score and S.D.**	**SCG Test Mean Score and S.D.**
Field Dependent (N = 75)	**64.0** (*12.2*)	**2.6** (*1.5*)
Field Neutral (N = 88)	**64.1** (*14.1*)	**3.6** (*1.8*)
Field Independent (N = 65)	**66.3** (*13.8*)	**3.9** (*1.6*)

Table 7.20: The distribution of the statistics examination mean score and the SCG test mean score according to field dependency categories (experimental group)

Field Dependency Categories (Comparison Group)	**Statistics Exam Mean Score and S.D.**	**SCG Test Mean Score and S.D.**
Field Dependent (N = 62)	**64.1** (*13.1*)	**2.0** (*1.3*)
Field Neutral (N = 57)	**64.9** (*14.9*)	**2.2** (*1.1*)
Field Independent (N = 45)	**66.4** (*12.5*)	**3.1** (*1.0*)

Table 7.21: **The distribution of the statistics examination mean score and the SCG test mean score according to field dependency categories (comparison group)**

In both the experimental and comparison groups, there appeared to be a trend where the mean score for the field independent category was greater than the mean score for the field neutral category which in turn was greater than the field dependent category's mean score. However, it was found that there were no differences in performance based on the mean statistics examination scores between these three categories of field dependency according to the analysis by ANOVA design (**Experimental group** : $F_{(2, 225)} = 0.65$, df = 2, p = 0.522; **Comparison group** : $F_{(2, 161)} = 0.38$, df = 2, p = 0.687). This result seemed to concur with the finding in the exploratory study. Thus, it can be inferred that the student teachers' degree of field dependency had no effects on their performances in the statistics examination.

For the SCG test, there were very significant differences among the mean scores obtained by the three field dependency categories in each of the experimental and comparison groups (**Experimental group** : $F_{(2, 225)} = 11.79$, df = 2, p < 0.001; **Comparison group** : $F_{(2, 161)} = 11.41$, df = 2, p < 0.001). Similarly, this result confirmed the finding in the exploratory study that student teachers' degree of field dependency affected their performances in the SCG test.

7.12.1 Responses to the Pre and Post Questionnaires According to Field Dependency Categories

To examine whether student teachers' degree of field dependency affected their responses to some of the items relating to attitudes and opinions in the pre and post questionnaires, an analysis using the chi-square test (as a test of homogeneity) was carried out. The analysis was done separately for each of the experimental and comparison groups. The full results from these analyses can be found in Appendix W. A summary of the results for the respective groups are as follows:

Experimental group

On attitudes toward learning statistics, there were only two items, which showed statistically significant differences that occurred between the field dependency categories: field dependent (FD), field neutral (FN) and field independent (FI). The first was the item 'I like to study statistics' which favoured the field independent student teachers ($\chi^2 = 6.0$, df = 2, $p < 0.05$). Over 63% of the FI students agreed with the statement as compared to 50% and just under 43% for the FN and FD categories respectively. The second item was 'I enjoy the statistics course that I am currently studying' ($\chi^2 = 10.8$, df = 4, $p < 0.05$) which again favoured the FI student teachers with about 54% supporting the statement.

While other items in the section on attitudes toward learning statistics showed no significant differences that occurred between the field dependency categories, there appeared to be a trend where a slightly higher proportion of the student teachers from the FD category than the other two categories concurred that 'Statistics is difficult to learn' (FD – 35%, FN – 25%, FI – 24%), 'A lot of difficult concepts in statistics' (FD – 47%, FN – 40%, FI – 29%), 'Statistics is a challenging subject' (FD – 78%, FN – 72%, FI – 72%), 'It would be easier to study statistical software packages' (FD – 66%, FN – 59%, FI – 59%) and felt that they lacked confidence in coping with the statistics course as they were with other courses (FD – 22%, FN – 13%, FI – 12%).

The main conclusion to be drawn from the section containing items about the student teachers' opinions on the introductory statistics course was that statistically significant differences did not occur between the field dependency categories. Nevertheless, it was again observed that a higher proportion of FD student teachers as compared to the student teachers in the other two categories found the statistics course to be difficult (FD – 22%, FN – 12%, FI – 11%), the lectures to be boring (FD – 41%, FN – 24%, FI – 26%), the course too mathematical (FD – 40%, FN – 34%, FI – 33%), too many tedious calculations involved (FD – 48%, FN – 42%, FI – 39%) and less emphasis was given to the interpretations of statistical results (FD – 45%, FN – 42%, FI – 36%).

There were two items on the opinions about how the student teachers would like to learn statistics best that showed statistically significant differences in the responses given by the respective field dependency categories. The items were:

- 'Need to have discussions between lecturer/students and student/student' (χ^2 = 12.7, df = 4, $p < 0.05$) which favoured the FD student teachers. 100% of them agreed with the statement compared to 89% and 87% of the FN and FI student teachers respectively.
- 'I do not need to understand the statistical concepts and interpretations to pass the course (χ^2 = 11.1, df = 4, $p < 0.05$). Only 6% of the FD student teachers agreed with this statement as compared to 13% and 19% of the FN and FI student teachers respectively.

Although the responses to the rest of the items in this section did not show that statistically significant differences occurred between the field dependency categories, again the patterns indicated that a slightly higher proportion of the FD student teachers preferred that the introductory statistics course to be student-based with a lot of practical work and group activities.

Comparison group

Overall, there were no statistically significant differences that occurred between the field dependency categories in all the aspects assessed (attitudes toward learning statistics and opinions about the introductory statistics course) in the pre-questionnaire except for one item concerning the student teachers' opinion on whether the statistics course was too mathematical or otherwise (χ^2 = 14.8, df = 4, $p < 0.01$). About 36%, 32% and 29% of the FD, FN and FI student teachers respectively believed that statistics course was too mathematical. On the other hand, about 38% of the FI student teachers believed that the course was not mathematical enough as compared to 20% and 9% of the FD and FN student teachers respectively.

As in the experimental groups, the results from almost all items consistently showed that a slightly higher proportion of the field dependent student teachers in the comparison group as compared to the other two categories tended to have more negative attitudes toward learning statistics and gave less favourable opinions on the introductory statistics course that they were enrolled into. For example, only 18% of the FD student teachers said that they enjoyed the statistics course when compared to 20% and 38% of the FN and FI student teachers respectively. About 40% of the FD student teachers agreed that the statistics lectures were boring while only about a quarter in each of the other two categories held similar view. A majority of the FD student teachers also agreed that the statistics course involved a lot of tedious calculations (compared to 42% of the FN student teachers and 37% of the FI student teachers).

On opinions on how they would prefer to learn statistics, the responses to most of the items given by the three field dependency categories appeared to be statistically homogeneous. It is interesting to note that almost every student teacher in all categories seemed to agree with the statement 'Need to have discussions between lecturer/students and student/student'. Nevertheless, it was also observed that a higher proportion of FD student teachers as compared to the other two categories disagreed that 'The lecturer gives all the input and the students take down the notes without question' (FD – 67%, FN – 48%, FI – 48%), 'Just have to memorise the facts and figures given by the lecturer' (FD – 77%, FN – 75%, FI – 62%), 'Do not need to do practical work in the classroom' (FD – 89%, FN – 87%, FI – 75%) and 'Tests and exam questions should focus more on the calculations rather than interpretations' (FD – 40%, FN – 52%, FI – 62%). On the other hand, a lower proportion of the FI student teachers as compared to the other two categories appeared to agree with the following statements: 'The teaching should be interactive and the lecturer's role is just as a facilitator' (FI – 53%, FN – 72%, FD – 73%) and 'The lecturer should use real life data in examples' (FI – 41%, FN – 48%, FD – 51%).

Overall, the field dependent student teachers in both experimental and comparison groups generally did not like the way the introductory statistics course was taught to them which was mostly through the lecture method. It can be argued that one of the reasons could be due to their inefficient note taking during lectures where they might have difficulty abstracting and organising information that was presented as part of a larger organised field as pointed out by Frank (1984). Due to their field dependent characteristics such as strong interpersonal orientation and greater sensitivity to social stimulation (Witkin & Goodenough, 1981), it was no wonder that the field dependent student teachers preferred group oriented and co-operative work situations in helping them to excel in learning statistics.

7.13 Conclusions

The results from the pre-questionnaire for both the experimental and comparison groups appeared to support the findings from the exploratory study. Most student teachers had positive attitudes toward learning statistics. However, some of them, like the male student teachers, those from the Non-Mathematics Education group and those who were field dependent learners, seemed to find the introductory statistics course to be difficult and the lectures to be boring and not enjoyable with the contents being too mathematical.

As a result of this experimental study which involved the learning units and the parallel lecture method, the following findings from the post-questionnaire and some assessment tasks were observed:

1. Student teachers from the experimental group who experienced the learning units were more likely than their counterparts from the comparison group to opt for learning statistics interactively and based on small group co-operative learning where they would be able carry out practical activities as well as having discussions with their fellow students and also their lecturer. They were also more likely to express disapproval of the 'spoon-fed' method where they would receive all the facts and figures from the lecturer, memorised and regurgitated them when the tests and examination came along. Instead, they believed that they needed to understand fully the statistical concepts and interpretations and also be taught of how to effectively use the statistical knowledge acquired and applied them in real life situations. However, it

must be noted that the majority of the student teachers in the comparison group also opted for a student-based approach to learning statistics but to a lesser extent.

2. The learning units that were based on the interactive and co-operative learning were well received by the student teachers in the experimental group. An overwhelming majority of them had favourable views about the learning units which were largely described as enjoyable and worthwhile.
3. Comparison between genders within each group revealed that a slightly higher proportion of the male student teachers preferred the course to be interactive involving working in groups with plenty of discussions. Similarly, the Non-Mathematics Education group also seemed to prefer this type of learning statistics.
4. The experimental group performed better in the SCG test than their fellow students in the comparison group. Perhaps, this could be due to the learning environment that the latter were exposed to through the learning units where it appeared that things learned tended to be retained longer in the memory while in the comparison group, perhaps not much learning could take place where the main activity of the student teachers was taking down notes!
5. As in the exploratory study, the female student teachers in both the experimental and comparison groups outperformed the male student teachers in the statistic examination. As expected, the Mathematics Education group performed better in the statistics examination than the Non-Mathematics Education group.
6. There was no statistically significant difference in the performances shown by the three field dependency categories in statistics examination although in both experimental and comparison groups, the field dependent category had a slightly better mean score than the other two categories. Nevertheless, the field independent student teachers performed significantly better in the SCG test than the other two categories. This was expected due to the nature of the SCG test which favoured those who were able to pick out the relevant responses from the irrelevant ones.
7. Overall, the field independent student teachers tended to like studying and enjoying the statistics course more than the other two categories. On the other hand, more field dependent student teachers were likely to say that the course was too mathematical, difficult and dull. They were more likely to enjoy a statistics course that involved learning in small groups and working co-operatively among themselves as shown by the results from the experimental study which involved the learning units.

CHAPTER EIGHT

RESEARCH STUDY THREE

8.1 Introduction

The main aims of the third stage of the research study were to explore student teachers' understanding of some probability and descriptive statistical concepts and also to seek their opinions about their readiness to teach statistics in school. In addition, student teachers who were formerly teachers themselves were asked about what kinds of statistics they used in school. These student teachers had previously attended the introductory statistics course when they were either in the first or second year of the Bachelor of Education (B.Ed) degree programme and were likely to be posted to schools the following semester as qualified graduate teachers. Some of them were also likely to teach statistics as part of the mathematics curriculum. Therefore, it was thought to be worthwhile to survey their basic knowledge and understanding of the probability and statistical concepts and also whether the training and exposure they obtained in the statistics and methodology courses prepared them well to teach statistics in school.

In this chapter, the methodology used in this study is discussed. Firstly, the sample and the study instruments used are described in detail. Finally, the results and analyses as well as the discussions of the findings are presented.

8.2 The Study Sample

In this study, the participants were final (fourth) year student teachers who were enrolled in a mathematics education course in methodology at Sultan Idris Education University (SIEU). In the methodology course, the student teachers were taught the theories and methods of teaching secondary school mathematics. Those enrolled in this course included student teachers from the Non-Mathematics Education programmes (Information Technology Education and Science Education) who also wished to teach mathematics in school as their second option subject once they graduated. The breakdown of the student teachers participating in this study according to gender and programmes of study is shown in Table 8.1.

Programme of Study	Male	Female	Total
Mathematics Education (ME)	52	116	168
Non-Mathematics Education (NME)	11	70	81
Total	63	186	249

Table 8.1: The breakdown of student teachers participating in the study

This study was carried out in a two-week period from 4 August 2003 until 15 August 2003.

8.3 The Study Instruments

The following assessment tasks were used in this study:

1. The Hidden Figures Test
2. The Digit Span Test
3. The Multiple-Choice Test
4. A Short Questionnaire

All the assessment tasks with the exception of the multiple-choice test were conducted in English. This was in line with the change in policy by the university authority, since the beginning of the first semester of the academic session 2002/2003, that emphasises the usage of the English Language for courses in science and mathematics. The multiple-choice test was still conducted in the Malay Language because the student teachers took the statistics course in that language prior to the change. Therefore, it would be unfair to the student teachers if the test were to be conducted in English. Discussions on the Hidden Figures Test and the Digit Span Task can be found in sections 6.3.3 and 6.3.4. The multiple-choice test and the questionnaire will now be described in turn

8.3.1 The Multiple-Choice Test

The multiple-choice test consisted of nine questions on probability and six questions on descriptive statistics. The questions on probability were adapted from a test devised by Hirsch & O'Donnell (2001) and also from the probability concepts test by Green (1982), while the questions on descriptive statistics were devised by the researcher himself based on the textbook by Freund & Perles (1999) used by the student teachers. The test questions are given below (see Appendix P for the test in its original form).

Question 1

a) A wooden cube the size of a normal die is painted black on one side and white the other side. With the black side face up, it is then tossed up in the air and lands on a flat surface. Which side is more likely to be face up ?

□ The black side □ The white side □ No difference

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 2

a) There are 22 blue marbles and 28 red marbles in a small black bag. A boy picks out a marble at random without looking. Which marble is he more likely to pick out ?

□ Blue □ Red □ Equal chance of picking out a blue or red

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 3

a) The first roll of a fair die results in a '6'.The die is rolled a second time. What is the chance that the second roll also results in a '6' ?

□ 1/6 □ 1/36 □ Slightly more than 1/6

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 4

a) A fair coin is tossed four times and 'Tails' appears every time. The coin is then tossed for the fifth time. Which of the following statements is most likely ?

□ 'Tail' is more likely to turn up again
□ 'Head' is more likely to turn up
□ 'Tail' is as likely to turn up as 'Head'

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 5

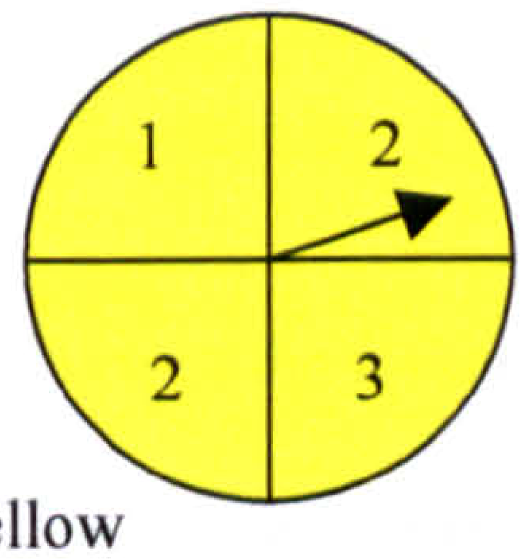
a) In a lucky draw, a customer is asked to pick out a gold coloured counter from one of two bags in order to win a prize. The customer knows that in bag X there are 3 gold coloured counters and 4 silver coloured counters while in bag Y there are 3 gold coloured counters and 3 silver coloured counters. Without looking into the bags, which bag gives the customer the better chance of picking out a gold coloured counter ?

□ Bag X □ Bag Y □ Doesn't matter which bag

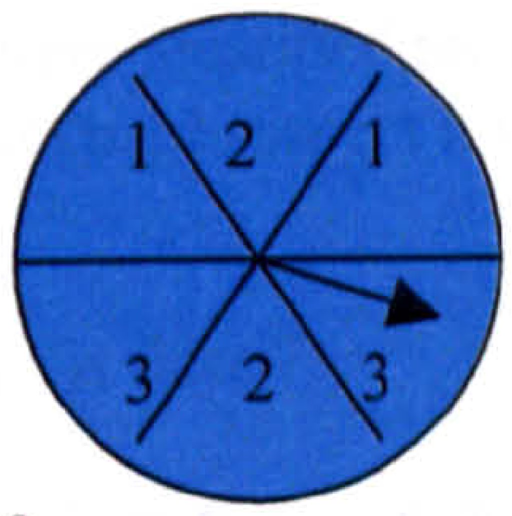
b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 6

a) There are 2 coloured discs; yellow and blue which are marked with numbers as shown in the diagram below. Each disc has a pointer which is spun and points to a number. With which disc is it easier to get a number '1' ?



Yellow



Blue

□ Yellow □ Blue □ Both discs have the same chance

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 7

a) A bag has 6 pieces of fruit: 2 pears, 2 oranges and 2 apples. 3 pieces of fruits are picked one at a time. Each time a fruit is picked, the type of fruit is recorded and it is then put back in the bag. If the first 2 fruits were oranges, what would the third piece be likely to be ?

□ A pear □ An orange □ An apple □ All are equally likely/same chance

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 8

a) A fair die is rolled four times. Which of the following ordered sequences of results is least likely to occur?

□ 3, 4, 5, 6 □ 2, 5, 5, 2 □ 1, 4, 3, 2 □ All sequences are equally likely

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 9

a) Which of the following is not true of probabilities ?

□ If it is impossible for an event to occur, the probability is 0
□ The probability of any event is greater than or equal to 0 but less than or equal to 1
□ For any events X, Y, the probability that one or other of them will occur is the sum of their probabilities ie P(X or Y) = P(X) + P(Y)
□ If the probability an event will occur is p, then the probability it will not occur is 1 - p

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 10

a) For the data 2, 3, 4, 4, 5, 7 which of the following is true ?

□ The mean and mode have the same value
□ The mean and median have the same value
□ The mode and median have the same value
□ The mean, mode and median all have the same value

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 11
a) For a set of data which contains extreme values, the best measure of location is

□ mean □ median □ mode □ first quartile or third quartile

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 12
a) Which of the following statements is false ?

□ The standard deviation of the numbers 6, 6, 6, 6, 6, 6, 6, 6 is 0
□ The sum of the deviations from the mean is always 0
□ If the sum of the squared deviations from the mean is divided by n-1, we obtain the sample variance
□ The sample variance is always greater than the sample standard deviation

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 13
a) Which of the following statements is true ?

□ Frequency polygon is a line graph of a cumulative frequency distribution
□ In a histogram, the widths of the rectangles represent the class frequencies
□ A stem and leaf plot would be most helpful in finding the median
□ The box plot consists of the first quartile, median and the third quartile

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 14
a) In order to compare the values of two numbers which belong to different sets of data, we use

□ the coefficient of variation □ z-scores □ Chebyshev's theorem □ the midrange

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Question 15
a) Which of the following does not involve descriptive statistics ?

□ summarising data □ presenting data □ generalising from data □ analysing data

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure, but I suspect it might be □ Just guessing

Each question consisted of two items: a) item on statistics/probability concept b) item on respondent's confidence. The second item was included so as to enable the respondents to express their certainty or uncertainty over the responses offered to them in the first item. This method has been proposed by many researchers such as Rippey (cited in Friel & Johnstone, 1978) who suggests that multiple-choice tests should be adapted to confidence-scoring procedures. With these procedures, a respondent's confidence in giving the correct response would also be rewarded. The following scoring scheme was employed for the multiple-choice test above:

- 3 marks would be awarded if the respondent gave a correct response and ticked the box 'Very confident'.
- 2 marks would be awarded if the respondent gave a correct response and ticked the box 'I cannot be sure, but I suspect it might be'.
- Only 1 mark would be awarded if the respondent gave a correct response and ticked the box 'Just guessing'.
- No mark would be awarded if the respondent gave an incorrect response irrespective of the box he ticked to indicate his level of confidence.

It must be pointed out that the student teachers were unaware of the scoring scheme described above. The researcher merely requested them to sincerely express themselves when giving the responses to the questions. Scores were also obtained through the conventional method where '1 mark is given to a correct response and 0 mark to an incorrect response' and then compared with the scores obtained with the method mentioned above.

8.3.2 The Questionnaire

The complete questionnaire is given below in Figure 8.1. The main purposes of this questionnaire were to find out what kinds of statistics did some of the respondents (who were former teachers) use when they were teachers in school and also to assess their confidence in teaching statistics if given the responsibility to do so. To assess the latter, the semantic differential method was employed (discussion on this method can be found in section 6.3.2). Personal information, such as gender, matriculation number and number of years of teaching experience, was also asked.

1. **Sex** : ☐ Male ☐ Female

2. **Matric. No.** : ....

3. **Semester of study** : ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

4. **Programme of study** : ☐ Maths Ed. ☐ IT Ed. ☐ Sc. Ed. ☐ Others

5. **Teaching experience in either primary or secondary school or both:**

   ☐ None
   ☐ Less than 5 years
   ☐ Between 5 and 10 years
   ☐ More than 10 years

6. **Have you had the experience of teaching statistics in school ?**

   ☐ Yes ☐ No

7. **As a teacher, which of the following statistics did you use in school?**
   (Please tick as many boxes as you wish)

   ☐ Calculate mean and standard deviation
   ☐ Finding median and mode
   ☐ Calculate range, quartiles and percentiles
   ☐ Construct frequency tables
   ☐ Construct dot diagrams
   ☐ Construct stem and leaf displays
   ☐ Draw histograms, frequency polygons and bar charts
   ☐ Construct pie charts and pictograms
   ☐ Draw ogives
   ☐ Construct box - and – whisker plots (boxplots)
   ☐ Calculate z- scores
   ☐ Calculate probabilities and odds
   ☐ Construct confidence intervals for means
   ☐ Perform t-tests to compare means between two group
   ☐ Perform analysis of variance to compare means between more than 2 groups
   ☐ Perform tests of hypotheses when conducting small researches
   ☐ Perform chi-squared tests to compare differences among proportions
   ☐ Calculate coefficients of correlation
   ☐ Performing nonparametric tests such as sign tests and Mann-Whitney test

8. **How did you do the statistics?**

   ☐ Manually with the aid of calculator
   ☐ Using statistical software packages
   ☐ Other method. Please specify ....

9. **Your opinions about teaching Statistics in school**
   Pairs of contrasting statements are given below. Tick the relevant box that best represents your view. The closest the tick to the statement (either left or right), the strongest the preference.

I don't have confidence in teaching statistics						I have confidence in teaching statistics
It is difficult to teach statistics						It is easy to teach statistics
It is easier to teach statistics than mathematics						It is more difficult to teach statistics than mathematics
I would include practical activities in teaching statistics						I would not include practical activities in teaching statistics
The statistics courses that I enrolled, did not prepare me well as a statistics teacher						The statistics courses that I enrolled prepared me well as a statistics teacher

Figure 8.1: The Questionnaire

8.4 Results from the Digit Span Backwards Test (DSBT)

The distribution of the DSBT scores is shown in Figure 8.2 and the descriptive statistics are as follows: mean score = 6.1, standard deviation = 1.4, median score = 6, minimum score = 3, maximum score = 9 and inter quartile range = 2. About half (50%) of the student teachers who sat for the test scored between 5 and 7 (inclusive). The distribution of the DSBT scores appears to be symmetrical with the median located in the middle of the box. Therefore, the assumption for normality for this distribution seems not unreasonable and this is exactly as expected with the size of the sample large enough (N = 249).

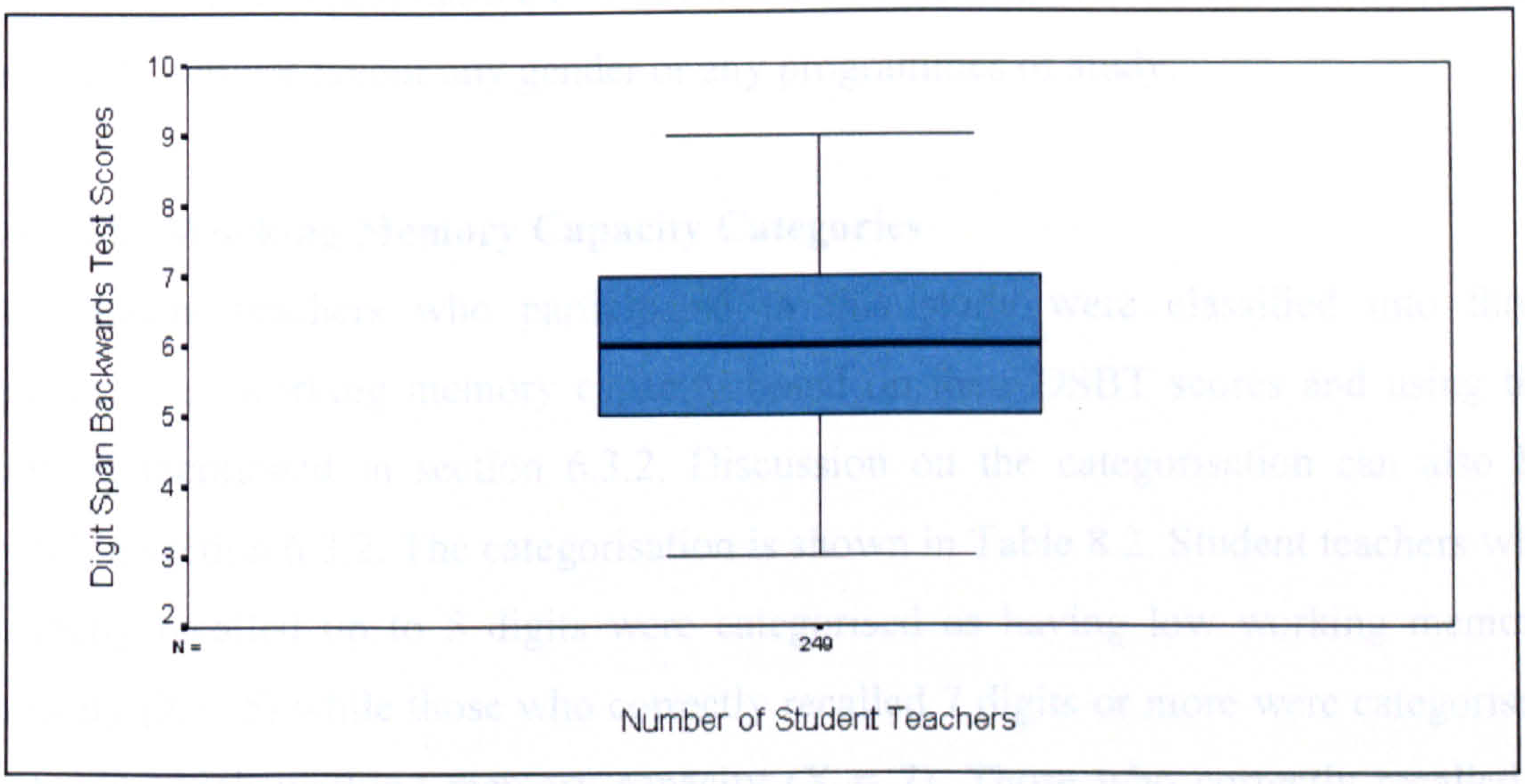


Figure 8.2: The Distribution of the DSBT Scores

It is interesting to note that the mean and median scores for this research study (mean = 6.1, median = 6) were both a unit less than the mean and median scores obtained in the exploratory study (mean = 7, median = 7). There is only one possible explanation for the difference observed: in the exploratory study, the test was conducted in the Malay Language (the mother tongue for most of the respondents) while in the current study, the test was conducted in English (a foreign language). Thus, the working memory space for most of the student teachers was used not only for holding and processing the information but also used for translating from English to Malay which could possibly take up some valuable spaces (as suggested by Johnstone, 1991). This seemed to concur with the findings of other researchers such as Selepeng (1996) who also observed a reduction in the capacity of the working memory of school children in Botswana when taking test in English instead of their native spoken tongue.

8.4.1 Comparison between Gender and between Programmes of Study

Since there were only a few male student teachers from the Non-Mathematics Education programme (N = 11), the 2 x 2 ANOVA design was not employed to study the effects of gender and programmes on DSBT scores so as to avoid the consequences on Type I or Type II error probabilities. Instead, a couple of t-tests were carried out. The results from the t-test analyses indicated that there were no significant between the genders ($t = -0.91$, $df = 247$, $p = 0.362$) and between programmes of study ($t = 0.21$, $df = 247$, $p = 0.832$). These results confirmed the finding from the exploratory study where no relationship was found between gender and DSBT scores as well as between programme of study and DSBT scores. Thus, it can be inferred that the DSBT did not favour any gender or any programmes of study.

8.4.2 The Working Memory Capacity Categories

The student teachers who participated in this study were classified into three categories of working memory capacity based on their DSBT scores and using the formula mentioned in section 6.3.2. Discussion on the categorisation can also be found in section 6.3.2. The categorisation is shown in Table 8.2. Student teachers who correctly recalled up to 5 digits were categorised as having low working memory capacity (X = 5) while those who correctly recalled 7 digits or more were categorised as having high working memory capacity (X = 7). Those who correctly recalled 6 digits were classified as the intermediate category.

Category of Working Memory Capacity	No. of Student Teachers
Low (X = 5)	83 (33.3 %)
Intermediate (X = 6)	82 (33.0 %)
High (X = 7)	84 (33.7 %)

Table 8.2: The Working Memory Capacity Categories

8.5 Results from the Hidden Figures Test (HFT)

The distribution of the HFT scores for all participants in this study is shown in Figure 8.3 with the following descriptive statistics: mean score = 8.4, standard deviation = 2.9, median score = 8, minimum score = 1, maximum score = 17 and inter quartile range = 4.5. As with the DSBT scores, the HFT scores also looks to be symmetrically distributed. Similarly, the assumption for normality for this distribution appears reasonable enough. Actually, this is a good thing since it indicated that varying degrees of field dependency were well represented in this study.

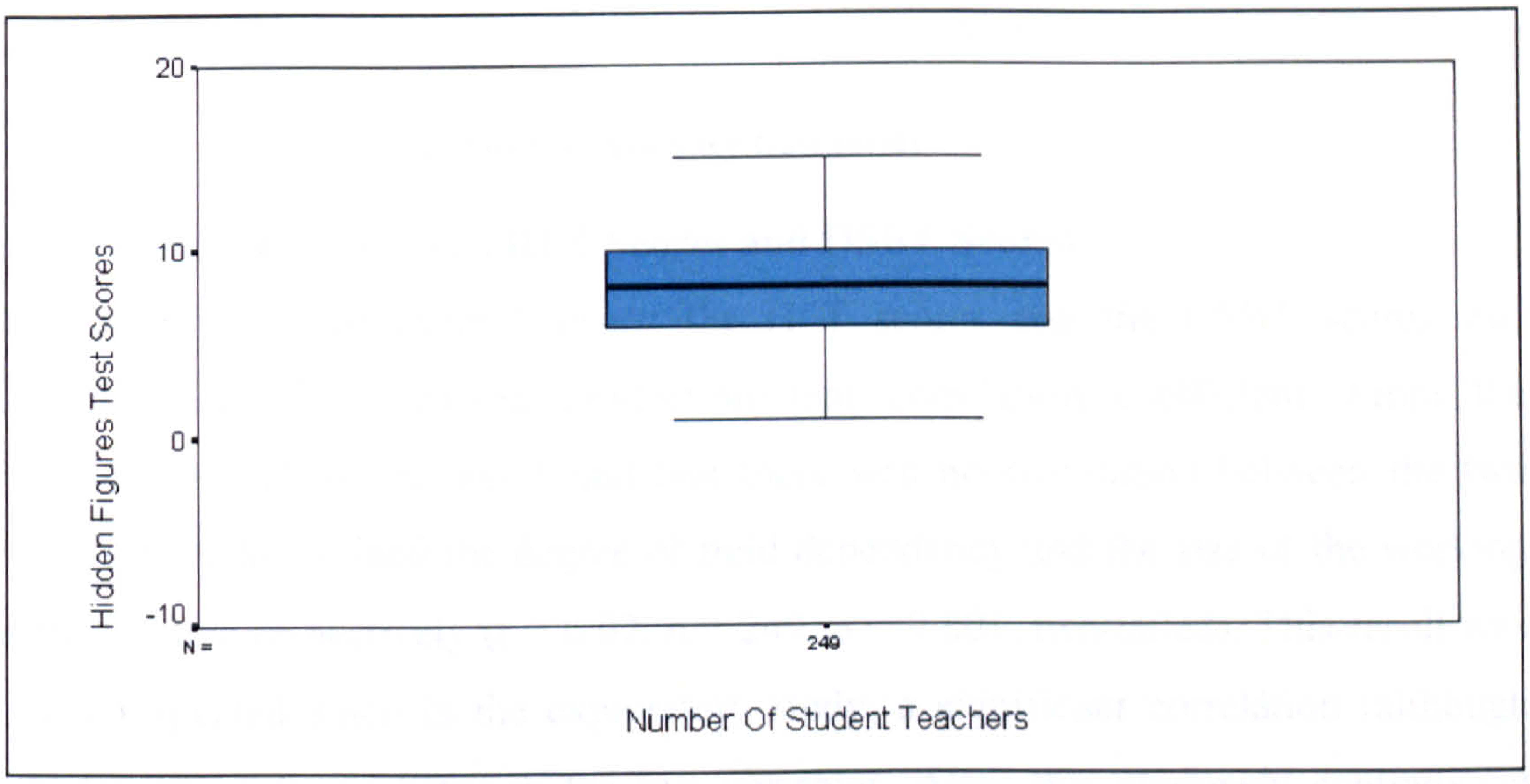


Figure 8.3: The Distribution of the HFT Scores

8.5.1 Comparison between Gender and between Programmes of Study

As with the DSBT, a couple of t-tests were carried out to study the effects of gender and programmes of study on the HFT scores. The results from the t-test analyses indicated that there were no significant between the genders ($t = 1.36$, $df = 247$, $p = 0.175$) and between programmes of study ($t = 1.06$, $df = 247$, $p = 0.292$). These results were similar to the results obtained from the exploratory study and the experimental study. Therefore, it can be inferred that the HFT did not discriminate between the genders or between the programmes of study.

8.5.2 The Field Dependency Categories

The student teachers were classified into three categories representing their levels of field dependency based on the HFT scores and the formula mentioned in section 6.3.3. The categorisation is shown in Table 8.3. Student teachers who scored 6 points or less were categorised as belonging to the field-dependent group while those who scored 11 points or more were classified as belonging to the field-independent group. Others who did not belong to either group were categorised as belonging to the field-neutral group.

Category of Field Dependency	No. of Student Teachers
Field Dependent	83 (33.3 %)
Field Neutral	84 (33.7 %)
Field Independent	82 (33.0 %)

Table 8.3: The Field Dependency Categories

8.5.3 Relationship Between HFT Scores and DSBT Scores

The degree of relationship between the HFT scores and the DSBT scores was measured using the Pearson product-moment correlation coefficient. From the correlational analysis, it was found that there was no correlation between the two scores which determined the degree of field dependency and the size of the working memory space respectively ($r = 0.02$, $n = 249$, $p = 0.801$, two-tailed). This result was quite unexpected since in the exploratory study, a significant correlation (although quite low) was found between the two variables. Also, this obviously contradicted with the findings of other researchers (e.g. Pascual-Leone, 1970; Berger, 1987; Al-Naeme, 1991; Bahar & Hansell, 2000) who suggest that the larger the measured working memory capacity of an individual, the more likely he is to be field independent.

If there were a significant positive correlation, one would expect to find more field independent individuals to fall in the high working memory capacity category and more field dependent individuals to fall in low working memory capacity category. However, it appeared that in this study, this was not necessarily the case. Table 8.4 shows the number of student teachers in the distribution of the joint working memory/ field dependency categories.

	Field Dependent	Field Neutral	Field Independent
Low WMC	26	31	26
Intermediate WMC	32	22	28
High WMC	25	31	28

Table 8.7: The Joint Working Memory/ Field Dependency Categories (No. of Student Teachers)

The table clearly shows that the number of field dependent student teachers who had low working memory capacity and those who had high working memory capacity was almost the same. Similarly, the number of field independent student teachers who had low working memory capacity and those who had high working memory capacity was almost the same too. Thus, it was not surprising that there was no significant correlation between the size of the working memory and the degree of field dependency.

8.6 Results from the Multiple-Choice Test

The distribution of the test scores based on the confidence-scoring procedures is shown in Figure 8.4 and it appears to be symmetrical. The descriptive statistics are as follows: mean score = 18.2, median score = 18, standard deviation = 5.8, minimum score = 2, maximum score = 34 (out of 45) and inter-quartile range = 7. Test scores were also obtained using the conventional method and the descriptive statistics are as follows: mean score = 7.4, median score = 7, standard deviation = 2.2, minimum score = 1, maximum score = 13 and inter-quartile range = 3. The two sets of test scores were found to be highly correlated (using the Pearson product moment correlation coefficient: $r = 0.86$, $n = 249$, $p < 0.0005$, two-tailed). This might indicate that student teachers that chose the correct responses did so confidently.

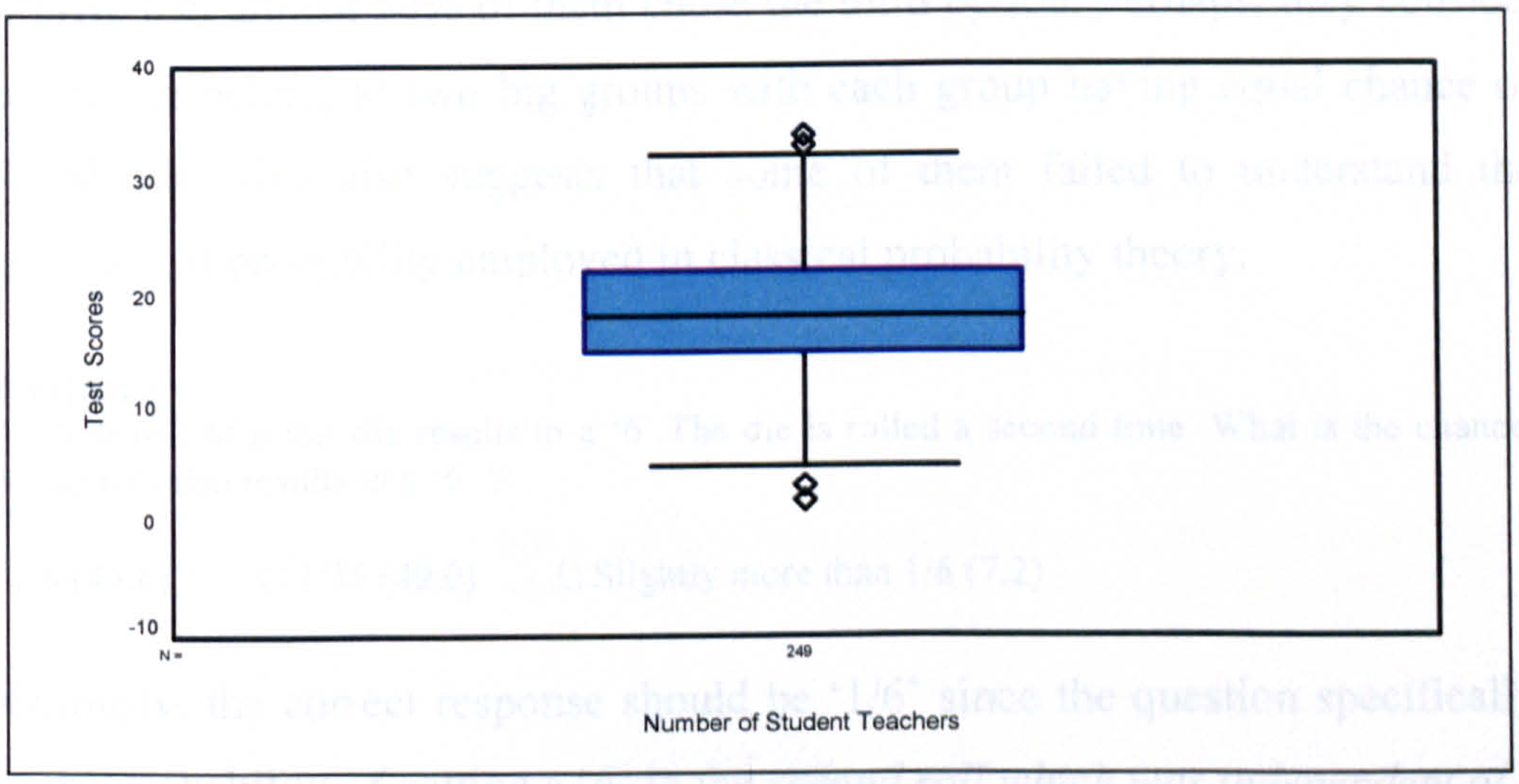


Figure 8.4: The Distribution of the Multiple-Choice Test Scores (NB: O represents outliers)

The questions are now discussed in turn. For each question, the percentages of the student teachers that opted for each option are given in brackets. The correct options are shown in bold.

Question 1

A wooden cube the size of a normal die is painted black on one side and white the other side. With the black side face up, it is then tossed up in the air and lands on a flat surface. Which side is more likely to be faced up ?

□ The black side (17.7) □ The white side (17.3) □ **No difference (65.1)**

Almost two third of the student teachers chose the correct response to this trivial question based on the classical probability concept of equally likely possibilities. The other third chose either 'The black side' or 'The white side'. This could be due to the 'recency effect' phenomenon where by emphasising that the cube was black face up in the first place, a significant number of student teachers would likely opt for black (positive recency – the next event to occur is likely to be the same as the previous one) or white (negative recency – the next event to occur is likely to be different from the previous one) being more likely the next time around.

Question 2
There are 22 blue marbles and 28 red marbles in a small black bag. A boy picks out a marble at random without looking. Which marble is he more likely to pick out ?

□ Blue (0.8) □ **Red (52.2)** □ Equal chance of picking out a blue or red (47.0)

The facility value for this question is quite low (0.52) considering the fact that the question is very straightforward. Obviously, a red marble is more likely to be picked out since there are more red marbles than blue marbles. However, it was quite a surprise that almost 50% of them chose the third option. Perhaps, they considered the marbles to belong to two big groups with each group having equal chance of being picked out. This also suggests that some of them failed to understand the basic definition of probability employed in classical probability theory.

Question 3
The first roll of a fair die results in a '6'.The die is rolled a second time. What is the chance that the second roll also results in a '6' ?

□ **1/6 (43.8)** □ 1/36 (49.0) □ Slightly more than 1/6 (7.2)

Obviously, the correct response should be '1/6' since the question specifically asked for the probability of getting a '6' in the *second roll which was independent of the first roll.* 49% of the student teachers chose the second incorrect option possibly because they misinterpreted the question as asking them to find the probability of getting a '6' in both rolls (combined events – getting a '6' in the first roll **and** getting a '6' in the second roll).

Question 4
A fair coin is tossed four times and 'Tails' appear every time. The coin is then tossed for the fifth time. Which of the following statements is most likely ?

□ 'Tail' is more likely to turn up again (25.3)
□ 'Head' is more likely to turn up (6.4)
□ **'Tail' is as likely to turn up as 'Head' (68.3)**

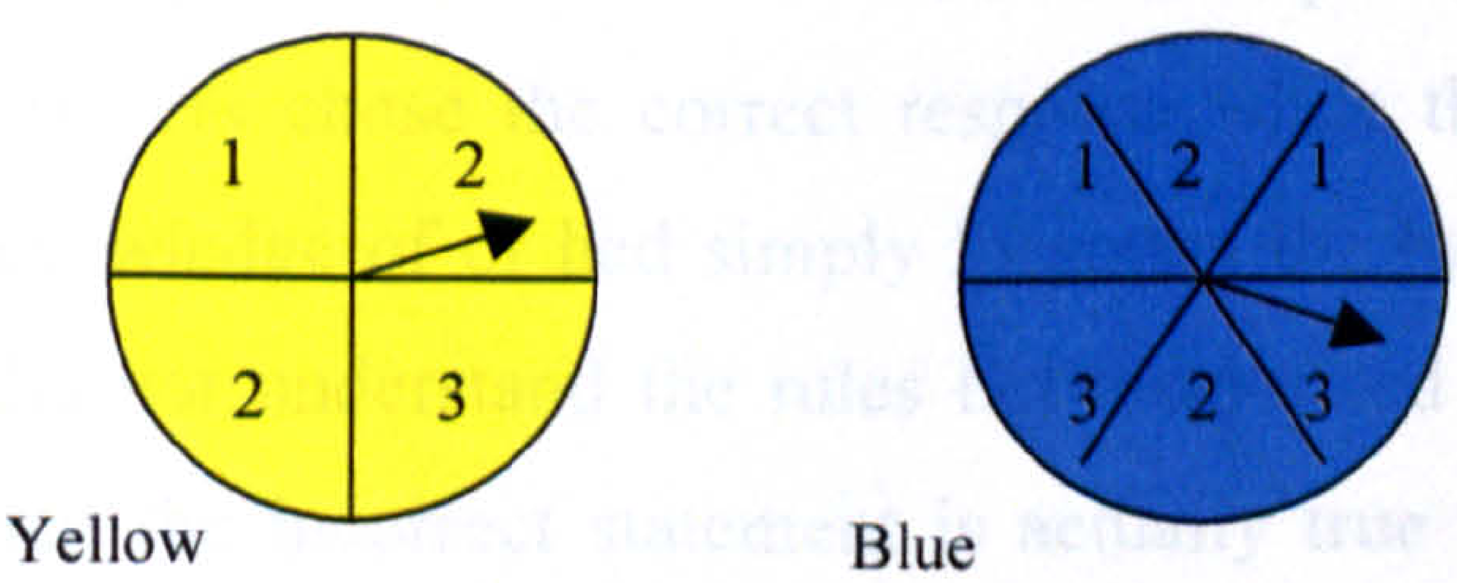
More than two-third of the student teachers chose the correct response, which might indicate that they understood the concept of equally likelihood. However, about a quarter of them chose the first option. Again, this was possibly due to the positive recency effect or simply misunderstood the idea of equally likely outcomes.

Question 5
In a lucky draw, a customer is asked to pick out a gold coloured counter from one of two bags in order to win a prize. The customer knows that in bag X there are 3 gold coloured counters and 4 silver coloured counters while in bag Y there are 3 gold coloured counters and 3 silver coloured counters. Without looking into the bags, which bag gives the customer the better chance of picking out a gold coloured counter ?

□ Bag X (12.4) □ **Bag Y (62.2)** □ Doesn't matter which bag (25.3)

This question is concerned with comparing ratios in the context of coloured counters (gold : silver) in bags (X and Y) and about 62% correctly chose 'Bag Y'. About a quarter of the student the student teachers chose the third option. Perhaps the same number of gold coloured counters in each bag influenced them to think that both bags had equal chance of picking out a gold coloured counter. Another 12% chose 'bag X' perhaps due to the greater number of total counters available.

Question 6
There are 2 coloured discs; yellow and blue which are marked with numbers as shown in the diagram below. Each disc has a pointer which is spun and points to a number. With which disc is it easier to get a number '1' ?



□ Yellow (20.5) □ **Blue (66.7)** □ Both discs have the same chance (12.8)

This is another question relating to the comparison of ratios. Two-third of the student teachers got this one right. About one-fifth of them who opted for 'Yellow' possibly thought that the area of the sector for '1' in the yellow disc was larger than either sector for '1' in the white disc.

Question 7
A bag has 6 pieces of fruits: 2 pears, 2 oranges and 2 apples. 3 pieces of fruits are picked one at a time. Each time a fruit is picked, the type of fruit is recorded and it is then put back in the bag. If the first 2 fruits were oranges, what is the third piece likely to be ?

□ A pear (11.6) □ An orange (2.0) □ An apple (13.2) □ **All are equally likely/same chance (73.2)**

More than 70% of the student teachers gave the correct response while about a quarter seemed to be affected by the positive recency phenomenon when they chose either 'a pear' or 'an orange'.

Question 8
A fair die is rolled four times. Which of the following ordered sequences of results is least likely to occur?

□ 3, 4, 5, 6 (22.6) □ 2, 5, 5, 2 (6.0) □ 1, 4, 3, 2 (4.8) □ **All sequences are equally likely (66.5)**

About two-thirds chose the correct response where they believed that all sequences of rolls have exactly the same probability of occurring. It is interesting to note that about 23% believed that the sequence '3,4,5,6' is the least likely to occur. Perhaps they thought that one is much more likely to get a mixture of different numbers than an ordered sequence.

Question 9
Which of the following is not true of probabilities ?

□ If it is impossible for an event to occur, the probability is 0 (28.5)
□ The probability of any event is greater than or equal to 0 but less than or equal to 1 (22.5)
□ **For any events X, Y, the probability that one or other of them will occur is the sum of their probabilities ie P(X or Y) = P(X) + P(Y) (34.9)**
□ If the probability an event will occur is p, then the probability it will not occur is 1 – p (14.0)

This question is about the basic rules of probabilities. Just above a third of the student teachers chose the correct response while the other two-third appeared to have no knowledge of or had simply forgotten the basic rules of probabilities. Possibly, they did not understand the rules but memorised them. However, it must be pointed out that the incorrect statement is actually true if X and Y are mutually exclusive and perhaps the student teachers just did not notice that the statement mentioned '**any events X, Y**'

Question 10
For the data 2, 3, 4, 4, 5, 7 which of the following is true ?

□ The mean and mode have the same value (9.6)
□ The mean and median have the same value (12.4)

☐ **The mode and median have the same value (63.5)**
☐ The mean, mode and median all have the same value (14.5)

Just over 63% managed to pick out the correct response which is quite a disappointing outcome since the question is quite trivial and requires minimal or no calculation at all. Possibly, the rest of the student teachers who chose the incorrect responses were confused with what the three measures of location (or measures of central tendency) represent.

Question 11
For a set of data which contains extreme values, the best measure of location is

☐ mean (15.7) ☐ **median (22.9)** ☐ mode (21.3) ☐ first quartile or third quartile (40.2)

It is disappointing to know that only 23% of the student teachers picked out the correct response. Surprisingly, about 40% chose the fourth option 'first quartile or third quartile'. It is quite difficult to figure out why this option was popular. Nevertheless, this question might indicate that the majority of the student teachers still did not fully grasp the meanings and definitions of the various measures of location.

Question 12
Which of the following statements is false ?

☐ The standard deviation of the numbers 6, 6, 6, 6, 6, 6, 6, 6 is 0 (11.6)
☐ The sum of the deviations from the mean is always 0 (38.6)
☐ If the sum of the squared deviations from the mean is divided by n-1, we obtain the sample variance (29.1)
☐ **The sample variance is always greater than the sample standard deviation (20.5)**

This question is about sample standard deviation and sample variance. The low facility value (0.21) might indicate that the majority of the student teachers did not really understand the formulas for sample standard deviation and sample variance. For example, almost 40% of the student teachers who thought that the statement 'The sum of the deviations from the mean is always 0' is false might not know what the expression 'sum of the deviations from the mean' (Σ (x - μ)) represents. Perhaps, those who did not choose **'The sample variance is always greater than the sample standard deviation'** as a false statement might erroneously think that by squaring a number would always yield an even greater number.

Question 13
Which of the following statements is true ?

☐ Frequency polygon is a line graph of a cumulative frequency distribution (19.7)
☐ In a histogram, the widths of the rectangles represent the class frequencies (36.1)

☐ **A stem and leaf display would be most helpful in finding the median (15.7)**
☐ The box plot consists of the first quartile, median and the third quartile (28.5)

The first, second and fourth options are obviously untrue but still an overwhelming majority of the student teachers (85%) opted for one of these options.

Question 14
In order to compare the values of two numbers which belong to different sets of data, we use

☐ the coefficient of variation (33.7) ☐ **z-scores (24.9)** ☐ Chebyshev's theorem (21.7)
☐ the midrange (19.7)

The most appropriate response is 'z-scores' which was correctly picked out by almost 25% of the student teachers. About a third of the student teachers opted for the option ' the coefficient of variation' which is quite puzzling since this measure is used to compare the relative variation between two sets of data. Another 40% chose either 'Chebyshev's theorem' (about the dispersion of a set of data) or 'the midrange' (the mean of the smallest and the largest values in a set of data). Perhaps, those who chose the incorrect responses did so by simply guessing and picking out any response at random.

Question 15
Which of the following does not involve descriptive statistics ?

☐ summarising data (21.3) ☐ presenting data (24.1) ☐ **generalising from data (31.0)**
☐ analysing data (22.9)

Only 31% of the student teachers realised that 'generalising from data' is not part of descriptive statistics. Those who opted for the other three options possibly showed that they did not really know what descriptive statistics is all about.

Overall, the student teachers performed satisfactorily in the probability section (Questions 1-9). A majority of them appeared to have no misconception about the concepts of equally likelihood, representativeness and comparison of ratios although their knowledge in basic rules in probability (such as that a probability value (p) must lie between 0 and 1 inclusive and what $p = 0$ or $p = 1$ represents) left much to be desired. In the descriptive statistics section (Questions 10 – 15), the majority of the student teachers performed dismally. Perhaps, they had mostly forgotten the concepts, definitions and theories of what they had learned and possibly memorised in the introductory statistics course earlier in their degree programme.

8.6.1 Comparisons between Gender and between Programmes of Study

Comparisons were made between genders and between programmes of study regarding performances in the multiple-choice test. The descriptive measures are given in Table 8.4.

	Min	Max	Median	1st Q	2nd Q	Meai	S.D.
Gender:							
Male (N = 63)	3	33	19	16	23	**19.0**	6.1
Female (N = 186)	2	34	18	15	21	**17.9**	5.7
Programme of study:							
Math. Ed (N = 168)	2	34	18	15	22	**18.1**	5.9
Non-Math. Ed (N = 81)	6	29	18	15	22	**18.3**	5.7

Table 8.4: Descriptive statistics for the multiple-choice test's distribution (comparison by gender and by programmes of study)

It appeared that between the genders, male student teachers performed slightly better than their female counterparts while between programmes of study, student teachers from the Non-Mathematics Education group performed as well as the student teachers from the Mathematics Education group. A couple of t-tests were carried out separately to investigate whether the mean scores obtained in the multiple-choice test were significantly different between the genders as well as between programmes of study. Since there were only a few male student teachers from the Non-Mathematics Education programme (N = 11), the 2 x 2 ANOVA design was not employed to study the effects of gender and programmes of study so as to avoid the consequences on Type I or Type II error probabilities. The results from the t-test analyses indicated that there were no significant between the genders (t = 1.75, df = 247, p = 0.085) and between programmes of study (t = 0.30, df = 247, p = 0.761). The correlational design using the Pearson product moment correlation coefficient also pointed to no significant relationship between the test scores and gender (r = -0.11, n = 249, p = 0.085, two-tailed) or between the test scores and programmes of study (r = 0.02, n = 249, p = 0.761, two-tailed).

8.6.2 Comparisons between Working Memory Capacity Categories and between Field Dependency Categories

The mean scores (and standard deviations) from the multiple-choice test obtained by the working memory capacity categories and the field dependency categories are shown in Tables 8.5 and 8.6 respectively.

Working Memory Capacity Category	Mean Scores (Std. Deviations in brackets)
Low (X = 5) (N = 83)	**15.9** *(5.6)*
Intermediate (X = 6) (N = 82)	**18.7** *(4.6)*
High (X = 7) (N = 84)	**20.1** *(5.3)*

Table 8.5: The Working Memory Capacity Categories

Field Dependency Category	Mean Scores (Std. Deviations in brackets)
Field Dependent (N = 83)	**17.6** *(5.6)*
Neutral (N = 84)	**18.3** *(6.0)*
Field Independent (N = 82)	**18.7** *(5.9)*

Table 8.6: The Field Dependency Categories

From Table 8.5, it was clear that the mean score for those in the high working memory capacity was much better than the other two categories while the intermediate category also showed a higher mean score than the low working memory capacity category. The one-way ANOVA design was used to test whether the differences among the mean scores were significant and this was found to be the case ($F_{(2, 246)} = 12.4$, $p < 0.001$). To identify which pair of categories significantly differed, the Bonferroni post-hoc test was used. (The Bonferroni test is a one-way ANOVA post-hoc tests that deals with pairwise multiple comparisons once it is determined that significant differences exist between means in the one-way ANOVA design).

Significant differences were found between the low working memory capacity category and the high working memory capacity category ($p < 0.001$) and between low working memory capacity category and the intermediate category ($p < 0.01$). The correlational design using the Pearson product moment correlation coefficient also confirmed the significant relationship between the Digit Span Backwards Test (to determine the size of the working memory) and the multiple-choice test scores ($r = 0.27$, $n = 249$, $p < 0.001$, two-tailed). The significant correlation was unexpected since it was initially thought that the items in the multiple-choice test did not overly burden the working memory of the student teachers. However, it should be pointed out that the test took place one or two years after the student teachers last studied statistics. In addition, the majority of the items were based on facts to be recalled correctly. Thus, it could be assumed that the test would be advantageous to student teachers with better long-term memory. According to Johnstone (1993), information stored and retrieved from the long-term memory plays a crucial role in aiding working memory to process new information and Maxwell *et al.* (2003) argues that the acquisition of long-term memory depends upon the availability of the working memory. Perhaps, it could be argued that the significant correlation between the test scores and working memory could be due to student teachers with high working memory space as having better long-term memory and student teachers with low working memory as having a poorer long-term memory.

Table 8.6 shows that the difference between the lowest mean score (obtained by the field dependent category) and the highest mean score (obtained by the field independent category) was quite small. Thus, it was not surprising that the analysis from the one-way ANOVA design concluded that there were no significant differences among the mean scores obtained by the respective field dependency categories ($F_{(2, 246)} = 0.72$, $p = 0.489$). In addition, the correlational analysis also indicated no significant correlation between the Hidden Figures Test (to determine the degree of field dependency) and the multiple-choice test ($r = 0.06$, $n = 249$, $p = 0.316$, two-tailed). It seemed that the ability to pick out the relevant information from the irrelevant ones did not play a significant part in determining success in the multiple-choice test and not like in the structural communication grid test where the individuals' degree of field dependency did really matter in determining success (see sections 6.9.3 and 7.12).

The effect from the combination of the two cognitive factors (working memory capacity and field dependency) on the student teachers' performances in the multiple-choice test was investigated using the two-way between subjects ANOVA design. The mean scores (in bold) and the standard deviations (in brackets) of the multiple-choice test for each joint working memory capacity and field dependency categories are given in Table 8.7

	Field Dependent	Field Neutral	Field Independent
Low WMC	**14.7** (5.7)	**15.7** (6.1)	**17.0** (6.6)
Intermediate WMC	**18.4** (4.4)	**18.5** (4.3)	**19.1** (5.4)
High WMC	**19.2** (6.1)	**19.7** (6.0)	**21.2** (4.5)

Table 8.7: The Joint Working Memory/ Field Dependency Categories and Test Mean Scores

The analysis showed that there was a significant main effect of the size of the working memory capacity on the multiple-choice test scores ($F_{(2, 240)} = 12.8$, $p < 0.001$) but the main effect of the degree of field dependency on the test scores was found to be not significant ($F_{(2, 240)} = 0.74$, $p = 0.481$). There was also no significant interaction between the size of the working memory and the degree of field dependency on the test scores ($F_{(2, 240)} = 0.76$, $p = 0.550$).

It can be clearly seen from Table 8.7 that the mean scores obtained by the joint low working memory and all field dependency categories (first row) were less than the mean scores obtained by the joint intermediate working memory and all field dependency categories (second row). The mean scores from the latter groups were in turn, less than the mean scores obtained by the joint high working memory and all field dependency categories. This indicated that the student teachers' degree of field dependency did not affect their performances in the multiple-choice test. Also, it was observed that the mean score obtained by the joint low working memory/field independent category was very much lower than the mean score obtained by the joint high working memory/field dependent category. This differed with the finding from the exploratory study (with the statistics examination scores, see section 6.9.4) and the findings from other researchers (e.g. El-Banna, 1986; Al-Naeme, 1991; Danili, 2001: Christou, 2001) where the mean scores from both joint categories were almost identical. Being field independent did not help to improve the performances in the multiple-choice test for those in the joint low working memory/field independent category. On the other hand, being field dependent did not necessarily hinder the performances in the test for those in the joint high working memory/field dependent category.

8.7 Results and Discussions from the Questionnaire

The student teachers (N = 249) in this study comprised of students with various backgrounds in teaching experience which is shown in Table 8.8.

Teaching Experience	Number of Student Teachers
None	89 (35.7%)
Less than 5 years	54 (21.7%)
Between 5 and 10 years	86 (34.5%)
More than 10 years	20 (8.1%)

Table 8.8: The Teaching Experience Categories

About one-third of the student teachers had no teaching experience whatsoever while the rest had teaching experience ranging from one year to more than ten years. Among the student teachers with teaching experience, 25 of them had the experience in teaching statistics (as part of mathematics) to lower secondary school pupils. Normally, they taught statistics, as they did in mathematics where computational procedures were emphasised and the formulas memorised.

Once they are posted to schools, all the student teachers would probably teach statistics as part of the mathematics curriculum. Therefore, in this short questionnaire, their opinions about teaching statistics in school were sought and the responses (in percentages with N = 249) were given in Table 8.9.

I don't have confidence in teaching statistics	12.0	27.3	38.9	13.3	8.4	I have confidence in teaching statistics
It is difficult to teach statistics	10.0	25.7	42.6	15.3	6.4	It is easy to teach statistics
It is easier to teach statistics than mathematics	6.8	11.2	45.0	22.5	14.4	It is more difficult to teach statistics than mathematics
I would include practical activities in teaching statistics	16.5	30.5	37.8	10.4	4.8	I would not include practical activities in teaching statistics
The statistics courses that I enrolled did not prepare me well as a statistics teacher	12.4	27.3	43.8	10.0	6.4	The statistics courses that I enrolled prepared me well as a statistics teacher

Table 8.9: Responses (in %) to the items on opinions toward teaching statistics (N = 249)

From Table 8.9, it appeared that just under 40% of the student teachers did not have the confidence to teach statistics as compared to only 22% who expressed confidence. Therefore, it was not surprising that about 36% believed that it would be difficult to teach statistics while about 22% thought it would be easy and also about

37% expressed the opinion that it would be more difficult to teach statistics than mathematics as opposed to 18% who thought otherwise. Perhaps, one of the reason student teachers lacked the confidence or would find it difficult to teach statistics was due to the inclusion of probability in the statistics curriculum where a considerable proportion of student teachers found that some of the probability concepts were difficult to understand.

About 40% of the student teachers thought that the statistics courses they had enrolled into did not prepare them well to teach statistics in school in contrast to about 17% who thought otherwise. Perhaps, this revelation was not unexpected since the statistics courses were taught in the traditional manner where algorithmic procedures were emphasised and not the statistical concepts and the interpretations behind them. Notwithstanding the training they received throughout their statistics courses, almost half of the student teachers (47%) aimed to include practical activities if given the opportunity to teach statistics in school.

Each pair of statements, as expected, correlated significantly (positively or negatively) with other pairs of statement. Results from the correlational analysis using the Kendall's tau (τ) statistics are shown in Table 8.10. The relationships between each pair of statements and the following variables: gender, programme of study, teaching experience, working memory capacity category and field dependency category were also investigated using the Kendall's tau statistics and all results are shown in Table 8.10 as well.

	1st Pair	2nd Pair	3rd Pair	4th Pair	5th Pair
2nd Pair	0.30 $p < 0.0005$	-	- 0.20 $p < 0.01$	- 0.21 $p < 0.01$	0.15 $p < 0.05$
3rd Pair	- 0.31 $p < 0.0005$	- 0.20 $p < 0.01$	-	0.19 $p < 0.05$	- 0.28 $p < 0.0005$
4th Pair	- 0.33 $p < 0.0005$	- 0.21 $p < 0.01$	0.19 $p < 0.05$	-	0.33 $p < 0.0005$
5th Pair	0.35 $p < 0.0005$	0.15 $p < 0.05$	- 0.28 $p < 0.0005$	0.33 $p < 0.0005$	-
Gender	0.16 $p < 0.05$	0.16 $p < 0.05$	n.s	n.s	n.s
Programme	n.s	n.s	n.s	n.s	n.s
Teaching Exp	0.27 $p < 0.0005$	n.s	- 0.17 $p < 0.05$	n.s	n.s
FD Cat.	n.s	n.s	n.s	n.s	n.s
WMC Cat.	n.s	n.s	n.s	n.s	n.s

Table 8.10: Correlation Coefficients Between Variables

From Table 8.10, it was clear that student teachers who did not express confidence in teaching statistics would probably find that statistics is more difficult to teach than mathematics. Perhaps, the belief that the statistics courses that they enrolled in did not prepare them well as a statistics teacher caused them to have apprehension about teaching statistics. However, they seemed to agree to include practical activities in teaching statistics which they did not experience in their previous statistics courses.

There were no significant correlations between any of the pair of statements and the following factors; programme of study, working memory capacity category and field dependency category. With gender, there were significant correlations with the following two pairs of statements:

a) 'I don't have confidence in teaching statistics – I have confidence in teaching statistics' – It appeared that female student teachers would have more confidence in teaching statistics than male student teachers.
b) 'It is difficult to teach statistics – It is easy to teach statistics' – More male student teachers than their female counterparts would find it difficult to teach statistics.

It was also observed that there were significant correlations between teaching experience and the following pairs of statements:

a) 'I don't have confidence in teaching statistics – I have confidence in teaching statistics' – Experienced student teachers were more likely to have confidence in teaching statistics which is really not surprising.
b) 'It is easier to teach statistics than mathematics – It is more difficult to teach statistics than mathematics' – Student teachers with less or no experience in teaching were more likely to find teaching statistics to be more difficult than teaching mathematics.

A survey of the kinds of statistics that teachers used in school was also carried out and 86 student teachers (all former school teachers) responded. A majority of them were familiar with calculating mean and standard deviation (100%), finding median and mode (92%), drawing histograms, frequency polygons and bar charts (92%), constructing pie charts and pictograms (85%) and constructing frequency tables (58%). Other descriptive measures such as calculating range, quartiles or percentiles and graphical displays such as constructing dot diagrams, box plots and stem and leaf displays were not popular with the former teachers. Perhaps there were no reasons for the former teachers to use such descriptive measures or graphical displays or simply because they did not know how to use them. About 42% knew how to convert raw scores (as in test and examination marks) into z-scores. As expected, only a very few of the former teachers made use of their knowledge in probability theory and inferential statistics when they were schoolteachers. Perhaps the teachers saw no need for them to use sophisticated statistics in their line of duty where simple descriptive statistics and simple graphical presentations were thought to be sufficient.

To calculate the statistics and draw or construct the graphical representations described above, the majority of the student teachers who responded to this question (93% of the 86 student teachers who responded) did them manually with the aid of calculators. Only 7% of them had the opportunity to use statistical software packages such as SPSS and Minitab or spreadsheet packages such as Microsoft Excel. The packages were not popular possibly because the former teachers themselves had no proper training or had no access to the packages.

8.8 Conclusions

Some of the major findings from this study were outlined as follows:

a) The mean size of the working memory space for the student teachers in this study was one unit less than the mean obtained by their counterparts in the exploratory study. This could be due to the language used in the test (DSBT) to determine the size of the working memory. In the current study, English was used while in the exploratory study; the instruction was in Malay Language. This is consistent with the findings by other researchers (e.g. Selepeng, 1995; Johnstone & Cassels, 1985) which according to Johnstone (1991) could be due to the working memory space being used not only for holding and processing but also for translating which could take up valuable space.

b) There was no significant correlation between the student teachers' working memory capacity and their degree of field dependency.

c) Performances in the multiple-choice test revealed some misconceptions and lack of understanding of the basic probability and descriptive statistical concepts among the student teachers. It appeared that some of them still did not fully grasp the idea of equally likelihood in the probability theory. They also displayed ignorance about the basic rules in probability and their knowledge of some descriptive statistical concepts were found to be wanting.

d) There was significant correlation between the size of the working memory space and the multiple-choice test scores but no correlation between the degree of field dependency and the test scores.

e) A significant number of the student teachers did not have confidence in teaching statistics. The reasons might be related to the difficulty in understanding some statistical concepts (especially in probability) and perhaps the statistics courses that they had attended, did not provide them with a good training to be a confident statistics teacher.

CHAPTER NINE

CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction

In this chapter, a summary of the thesis's findings will be outlined. This will be followed by some discussions on the limitations of this study. Finally, some recommendation on student teachers' learning statistics as well as suggestions for further work will also be put forward.

9.2 Summary of the findings

The first stage

Overall, the student teachers who were surveyed had positive attitudes toward learning statistics. However, a majority of them seemed to display an antipathy to the introductory statistics course on which they were enrolled. These student teachers also agreed that the course was rather difficult. It appeared that these negative attitudes were more prevalent among males than females, among Non-Mathematics Education (NME) student teachers than their Mathematics Education (ME) counterparts and among field dependent (FD) student teachers than field independent (FI) student teachers. One of the reasons might be that the content of the statistics course was deemed too mathematical and put much emphasis on computational techniques and algorithms. It also appeared that they did not learn much about the statistical concepts or how to apply them in everyday situations. Another reason cited was on the delivery of the statistics course that was mainly through the lecture method. A majority of the student teachers found the lectures uninteresting or dry since there was nothing else for them to do during the lectures except listening passively and take down notes. Thus, it was doubtful whether they could learn with understanding with that kind of teaching strategy. As pointed out by many statistics educators (e.g. Roiter & Petocz, 1996; Yilmaz, 1996), statistical knowledge gained by listening passively, without active participation by the students themselves, is not really assimilated and there is a tendency for saturation to set in very quickly.

Perhaps it was not surprising that attitudes toward the introductory statistics course were also mirrored by the performances in statistics tests and examination where the females performed better than the males and similarly, the ME student teachers were better than the NME student teachers. There were also other factors that could contribute toward the differences between males and females and between NME student teachers and ME student teachers such as different entry levels criteria and also slightly different attainments in mathematics. The student teachers' working memory capacity correlated significantly with their performance in statistics examinations suggesting that some items in the examination had placed excessive demand on the student teachers' working memories. On the other hand, student teachers' degree of field dependency seemed to have no influence on their performance in statistics examination. This might suggest that the items in the statistics examination were relatively straightforward, merely testing the outcomes of algorithmic learning and did not contain any irrelevant information.

The structural communication grid (SCG) test revealed that many student teachers did have misconceptions about some basic concepts in descriptive statistics and probability. This reinforced the perception that the introductory statistics course, which was delivered through the lecture method, did not offer the student teachers the best way to learn with understanding. There was no significant difference in the SCG test's performance between the males and females. However, as expected, significant difference was observed between ME and NME student teachers where the latter performed less well than the former. Not surprisingly, the field independent student teachers showed significantly better performance in the SCG test than the field dependent student teachers due to their superior ability in picking out the relevant boxes in the SCG to get the correct responses.

The second stage

In the second stage, results from the pre-questionnaire for both the experimental and comparison groups, concurred with the findings in the first exploratory stage concerning the student teachers' attitudes toward learning statistics and their opinions regarding the introductory statistics course. Student teachers liked to learn statistics but appeared to have reservations about the introductory statistics course.

Student teachers in the experimental group were exposed to the learning units which were based on interactive and cooperative learning strategies while their counterparts in the comparison group were given the same learning materials but delivered through the lecture method. Results from the post-questionnaire showed that the experimental group viewed the learning units favourably and enthusiastically and an overwhelming majority of them wished that the introductory statistics course to be similar to the learning units that they had just experienced. On the other hand, the comparison group showed little enthusiasm for the materials given through the lectures. However, they too expressed preferences towards a student-based approach in learning statistics that involved the interactive and cooperative learning strategies. In looking at the preference for this approach, males, NME student teachers and field dependent students were particularly positive about it.

An analysis of the results from the SCG test based on the learning materials indicated that the experimental group performed very significantly better than the comparison group. This could possibly be due to the learning environment that the student teachers in the experimental group were exposed to and where it appeared that things that were learned tended to be retained longer in the memory. On the other hand, not much learning could take place in the comparison group where the main activity of the student teachers was merely to take down notes. As expected, the field independent student teachers in both the experimental and comparison groups performed significantly better than the field dependent student teachers in the SCG test. This generally concurred with other research findings (as well as the finding from the first stage) which pointed to the superior performance of the field independent students over their field dependent counterparts in this type of test.

The analysis carried out using the statistics examination scores obtained at the end of the semester revealed that there was no significant difference between the experimental and the comparison groups. As in the first exploratory stage, female student teachers in both the experimental and comparison groups outperformed the male student teachers in the statistics examination. Similarly, the ME group performed better than the NME group. However, there was no significant difference in the performances shown by the three field dependency categories in the statistics examination possibly because the items asked in the examination were straightforward and did not include tasks that required them to differentiate between the relevant and irrelevant information

The third stage

Results from the third stage showed that student teachers (in their final year of study) still lacked understanding of some basic probability and descriptive statistics concepts, despite having enrolled in the introductory statistics course in the previous semesters. Arguably, this reflected the weakness of the introductory statistics course that relied heavily on the transmission of information via the lectures which are more likely dependent on algorithmic-based approach and recall but not on the understanding of the concepts. The finding from the multiple-choice test concerning the probability and statistics concepts revealed that any statistical knowledge the student teachers might had gained from the introductory course, seemed to have been forgotten or was not retained in their long-term memory beyond the termination of the course. The statistical analysis that was carried out also showed a significant positive correlation between the multiple-choice test scores and working memory which perhaps suggests that student teachers with high working memory capacity as having better long-term memory and student teachers with low working memory capacity as having poorer long-term memory. This explanation was plausible since many researchers (e.g. Johnstone, 1993; Maxwell *et al.*, 2003) have argued that the acquisition of long-term memory depends upon the availability of the working memory.

It was interesting to note that the mean size of the working memory capacity in this stage of the study was one unit less than the mean obtained by the student teachers in the first exploratory study. Arguably, this could be due to the language used in the test to determine the size of the working memory capacity (English in the current study and Malay in the exploratory study). Recent studies (e.g. Johnstone, 1991; Selepeng, 1995) have shown that learning science and mathematics in a second language can provide obstacles to understanding because the working memory space is used not only for holding and processing but also for translating which takes up valuable space. This might have implication for student teachers in learning statistics since English (as a second language) is currently being adopted as the medium of instruction for science and mathematics at the tertiary level in Malaysia.

Opinions were also sought from the student teachers about their confidence in teaching statistics in school once they graduated from the university and it seemed that a significant number of them did not have that confidence. It could be argued that this might be related to the difficulty in understanding some statistical concepts and possibly the statistics course itself which did not provide the student teachers with a good training to be confident statistics teachers.

9.3 Limitations of this Study

This was a ground-breaking study into student teachers' learning statistics which not only involved attitudinal study but also psychological characteristics that might affect their learning. As such, some limitations are evident.

One major limitation to this study was that it was carried out only in Malaysia and only applied to student teachers. It would be interesting to know whether the findings from this study would be similar if conducted in other countries (e.g. Scotland) or involved other students (e.g social science and psychology students). In each of the stages, the study was carried out when the student teachers were just part way through the introductory statistics course that they were enrolled into. Thus, attitudes toward learning statistics might arguably have just been formed and only a few statistical topics had been covered. Therefore, it would be interesting to assess their attitudes at the end of the course and also to identify misconceptions (through the tests) that might exist not only concerning descriptive statistics and probability but also on concepts in inferential statistics. However, due to time and organisational constraints, this could not be carried out.

In the second stage, the experimental study compared the interactive-based cooperative learning strategy (using the learning units) with the lecture method. It involved only a few topics in statistics and was carried out over five sessions (each session lasted about one hour). Thus, firm conclusions could not be drawn about the superiority of the learning units over the lecture method even though an overwhelming majority of the student teachers appeared to favour the former. Perhaps, the reason could be the novelty of the learning units. Thus, a longitudinal study over a semester and covering every topic in the course's syllabus might provide useful information about the effectiveness of the learning units in helping the student teachers to learn statistics. However, research in other areas has also demonstrated the value of this approach, which is applications-led, and involves subject matter that is being developed on a 'need-to-know' basis (Reid, 2003)

9.4 Recommendations for Student Teachers' Learning Statistics

One of the main findings from this study showed that the student teachers were in favour of learning statistics using the cooperative learning strategies involving discussions with fellow students and engagement with the course material. Thus, to foster positive attitudes toward the introductory statistics course and to promote learning with understanding, the traditional style of teaching statistics through lectures with much emphasis on giving students rules and techniques to memorise and drill set for practising algorithms, should be abandoned. However, this is not a recommendation to dispense with lectures! This study proposes that the traditional emphasis needs radical change. Instead, the focus in teaching statistics should be more applications-led and should enable the student teachers to realise how statistics could be used positively in making decisions and choices.

If student teachers were to learn statistics effectively, the following strategies (based on the findings from this thesis) should be adopted for implementation in the introductory statistics course:

a) *Exploration and experimentation should precede formal algorithms and formulas. Student teachers should learn by active involvement in learning activities such as collecting data themselves, asking questions about something in their environment and finding quantitative ways to answer them. In addition, real data and hands-on experience in working with data should be used whenever possible. It is a well-known fact that students learn to do well only what they practise doing. It was evident from the findings of the second stage research study that an overwhelming majority of the student teachers preferred this strategy and also they performed better than those who learned mainly through lectures (see pages 161-165 and 171-172).*

b) *The emphasis in all work should be on the analysis and the communication of this analysis in contrast to a focus on a single correct answer. Moreover, different approaches and solutions for a problem should be discussed and evaluated with opportunities provided for the student teachers to reflect. The learning units that were used by the experimental groups in the second stage of the research study that based on* *the cooperative learning method provided the student teachers with the opportunity to do just that (see pages 143, 161-165).*

c) *Lecturers should not underestimate the difficulty student teachers have in understanding basic probability and descriptive statistics concepts (see results from the SCG tests – pages 123-126, 166-170 and the multiple-choice test – pages197-202).*

d) *Lecturers should also be aware that learning becomes less efficient as the mental load the student teachers have to carry increase. There is a potential for overload when skills, observations and interpretation are dealt with simultaneously. Furthermore, results from this study had shown that working memory of a learner has the potential to be overloaded due to learning in a second language (see page 193).*

e) *Lecturers should also consciously teach strategies to help student teachers to pick out relevant information from the irrelevant. Results from this study had shown that field dependent student teachers were likely to be distracted by irrelevant information they encountered during lectures or in learning contexts which were highly unstructured (see pages 136, 139, 180, 183).*

In addition to the above strategies, a review of the relevant literature on statistics education also suggests the following approaches for student teachers to learn statistics effectively:

f) *Calculators and computers should be used to help student teachers visualise and explore data and to facilitate analysis and interpretation (Garfield, 1995: Riggs, 2003).*

g) *Student teachers should be made to realise that statistics should be a vehicle to make connections within mathematics and to form links with other disciplines (Burrill, 1993).*

h) *Since most students learn to value what they know will be assessed, a variety of approaches should be used for student assessment such as practical report, projects, journals as well as traditional tests and examinations (Burrill, 1993: Garfield, 1995; Ovett and Reenhouse, 2000).*

9.5 Suggestions for Further Research

There are many areas that could be derived from this study, in which further work might be carried out. Some future work that could be considered includes:

a) *a longitudinal study of the effectiveness of the learning materials incorporating the cooperative learning strategies on student teachers learning introductory statistics.*

b) *an investigation into the student teachers' performance in statistics now that the medium of instruction has been changed from Malay to English.*
c) *an investigation of how lecturers of the introductory statistics course could be effective in transmitting the subject matter and how student teachers should learn and take notes during a lecturer if the former could not do away with the lecture method.*
d) *an investigation into the effects of the psychological characteristics (working memory, field dependency and convergent/divergent styles of thinking) on student teachers' performance in the assessment procedures proposed in the recommendations such as reports and projects.*
e) *a longitudinal study of how newly qualified mathematics teachers approach the teaching of statistics in school.*

Hopefully, this suggested work can be carried in the near future not only in Sultan Idris Education University but also in other teacher training colleges and schools in Malaysia in order to make the learning of statistics to be more meaningful and practical to students. In a nutshell, this project has sought to demonstrate statistics as a tool to interpret and make sense of many aspects of life. All of us need to be equipped to appreciate the use of this tool. Some of us need to be equipped to teach it while others need to be equipped to do it!

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Statistical analyses and tables

Appendix A

The introductory statistics course syllabus at Sultan Idris Education University

Introductory Statistics Syllabus (PMS 1033)

Science and Technology Faculty

Sultan Idris Education University, Tanjung Malim, Malaysia

	Descriptions
1	**Summarising Data** a) Listing and Grouping – Dot Diagrams, Stem-and-Leaf Displays, Frequency Distributions, Graphical Presentations b) Statistical Descriptions – Measures of Location: Mean, Weighted Mean, Median and Other Fractiles (Box Plot for Graphical Representation), Mode. Measures of Variation: Range, Variance, Standard Deviation. The Description of Grouped Data
2	**Probability** Counting, Permutations, Combinations, Sample Space, Events, Basic Rules of Probability, Probabilities and Odds, Addition Rules, Conditional Probability, Independent Events, Multiplication Rules
3	**Probability Distributions** a) Discrete Distributions – Binomial Distribution, Hypergeometric Distribution, Poisson Distribution, Multinomial Distribution, Chebyshev's Theorem b) Continuous Distributions – Normal Distribution, Some Applications, The Normal Approximation to the Binomial Distribution
4	**Sampling and Sampling Distributions** Random Sampling, Sampling Distributions, Standard Error of the Mean, Central Limit Theorem
5	**Problems of Estimation** Estimation of Means, Confidence Intervals for Means, Estimation of Proportions
6	**Tests Concerning Means** Tests of Hypotheses, Significance Tests, Tests Concerning Means (Large And Small Samples), Differences between Means (Large and Small Samples, Paired Data)

7	**Tests Based on Count Data** Tests concerning Proportions, Differences Between Proportions, Differences Among Proportions, Contingency Tables, Goodness of Fit
8	**Regression and Correlation** Curve Fitting, Method of Least Squares, Regression Analysis, Coefficient of Correlation, Interpretation of r, Significance Test for r
9	**Non-Parametric Tests** One-Sample Sign test, Paired Sample Sign Test, The U-Test, Rank Correlation

Appendix B

The introductory statistics final examination paper for semester II 2001/2002

Statistics Examination Paper (PMS 1033) Semester 2 2001/2002

Time: 2 hours 30 minutes

Direction: Please answer ALL questions

1. The height of 70 members of the Boy Scouts group from a local school are recorded and tabulated below:

Height (cm)		Frequency		
140-150		3		
150-160		12		
160-170		19		
170-180		28		
180-190		6		
190-200		2		

(i) Complete the table above and then construct an ogive for the cumulative distribution of the boy scouts' height.

(ii) From the ogive drawn, estimate the percentage of the boy scouts whose heights are at least 180cm.

(iii) Estimate the percentage of the boy scouts whose height are between 150-170 cm.

(iv) What is meant by 'median' for a set of data? Estimate the median for the original set of data above.

2. (a) A box contains six blue pens, three green pens, five black pens and two red pens. A pen is randomly picked out from the box. What is the probability that

(i) a green pen is picked out

(ii) a red or a black pen is picked out

(iii) a pen other a blue pen is picked out

(b) A box is filled with two red marbles, three green marbles and a blue marble. Another box is filled with two dice. A marble is taken out from the first box and both dice are tossed out onto a smooth surface.

Let A = {to get a red marble} and B = {both dice show the same number of dots}. Evaluate $P(A \cap B)$.

(c) A student was absent on the very first day of the new school term. The most common reasons for absenteeism on the first day are 'not feeling well', 'miss the bus' or both. From the previous records, 3% of the students tend to fall sick on the first school day. 50% of those who fall sick also miss the bus. About 2% miss the bus and thus fail to turn up on the first school day.

Find the probability that the student who was absent on that day fell sick and was also known to miss the bus.

3. (a) Please refer to the experiment mentioned in Question 2 (a). Let suppose that we are interested in the colour of the pen that is being drawn out.

(i) State the sample space for the outcome of the experiment.

(ii) If X is the random variable concerned, what are its values? Write down the cumulative distribution function of X.

(iii) Calculate the mean and variance for X.

(b) Given that X is continuous random variable.

(i) Give the definition of density function of X

(ii) If X has a density function of $x^2 / 9$ with the bounded interval [0, c], find the value of c.

(iii) Calculate P $(1 < X < 2)$. Sketch the graph to represent this value as the area under the curve of density function.

4. (a) An intensive training that would take 15 days was planned for the university's tennis team in preparation for an inter-varsity tournament. The coach feared that rain could disrupt his plan. From the previous records, the probability that it would rain on any particular day at this time of the year was 0.3. Find the probability that

(i) there were at least 12 days without rain

(ii) there would be no rain between 8 to 14 days

(iii) rain would fall on the last day of training

(b) The average number of visitors who accessed a particular personal web site was 3 per day. The proprietor of the web site would like to study the number of visitors expected between 1 January until 1 March 2001 inclusive.

(i) What is the probability that there were at least 5 visitors on 1 February 2001?

(ii) In a space of 60 days, what is the probability that the number of visitors were 200 or more?

5. (a) A group of 32 Mathematics Education student teachers from a local university was chosen at random and their Cumulative Grade Point Average (CGPA) for the semester were obtained as follows:

3.1	1.9	1.7	1.6	3.2	2.7	2.6	2.9
2.7	2.1	2.2	3.9	2.5	1.9	3.4	3.3
1.8	3.5	3.9	1.7	1.8	3.5	1.9	2.2
2.8	2.1	3.1	1.9	3.3	2.6	2.8	2.6

Estimate the 98% confidence interval for the mean CGPA score obtained from the group of student teachers given that $\Sigma x = 83.2$ and $\Sigma x^2 = 230.68$

(b) A group of teachers from the same school lived in the same housing estate not far from the school. The time taken to commute from the housing estate to the school was on average 35.0 minutes with a standard deviation of 7.6 minutes. A diversion was constructed along that particular route so as to facilitate the process of widening the road. A survey was carried out to see whether the diversion had increased the time taken to travel from the housing estate to the school and the result indicated that the new mean was 39.4 minutes.

Does this show that the time taken to commute has increased? State any assumptions clearly in carrying out the relevant hypothesis test.

Appendix C

The digit span test

The Digit Span Task

The following tasks are administered separately. For both tasks, each of the digits in the series is read out loudly and clearly at a rate of one digit per second. The series denote the number of digits in an item. To signal the end of each series, the pitch of the voice should drop dramatically with the last digit.

A. The Digit Forward Task

The following instruction will be read out:

'In a fairly simple task, I'm going to read out some numbers. Please listen carefully to them since there will be no repetition. Once I stop speaking, only then are you allowed to write the numbers down in the space provided on the sheet that has just been handed out to you. Are you ready? Let us begin'.

Series	Digits
3	8 5 7 4 9 6
4	9 3 4 6 8 7 2 5
5	6 3 5 8 7 4 7 1 3 2
6	7 8 4 2 9 3 3 7 4 9 1 6
7	6 8 3 9 7 1 4 8 2 4 7 1 9 5
8	7 4 6 9 1 8 2 5 4 7 5 1 9 2 8 3
9	8 6 5 2 4 9 3 1 7 4 8 7 1 5 3 8 6 2

B. The Digit Backward task

The following instruction will be read out:

'Now I' going to read out another series of numbers but there will be a slight complication this time around. Once I have finished reading out each set of numbers, you are required to write them down in a reverse order. For example, if I say, '3 8 2 5', then you shall write down '5 2 8 3' Remember, do not write from right to left. Your task is to listen carefully, turn the number over in your mind and write from left to right. Any question? If every one is clear, then let's begin'.

Series	Digits
3	3 6 7 5 9 2
4	9 5 2 6 4 7 2 3
5	1 6 5 7 5 2 4 1 9 2
6	7 3 4 0 9 3 2 7 5 6 1 9
7	6 2 3 7 8 1 6 8 0 3 2 4 7 5
8	9 6 7 4 3 8 2 5 6 7 6 1 9 4 8 3
9	5 6 9 2 4 8 3 2 7 4 8 7 1 9 3 8 6 1

Appendix D

The hidden figures test

Name: ____________________

Matriculation No. ____________________

Programme of Study: ____________________

SHAPES

Shape recognition within complex patterns

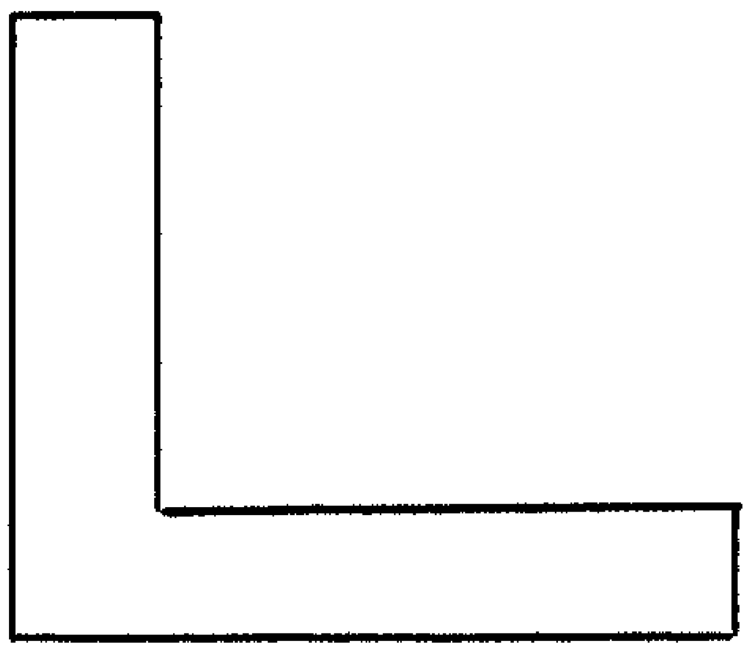
This is a test of your ability to recognize simple SHAPES, and to pick out and trace HIDDEN SHAPES within complex patterns. The results will not affect your course assessment in any way.

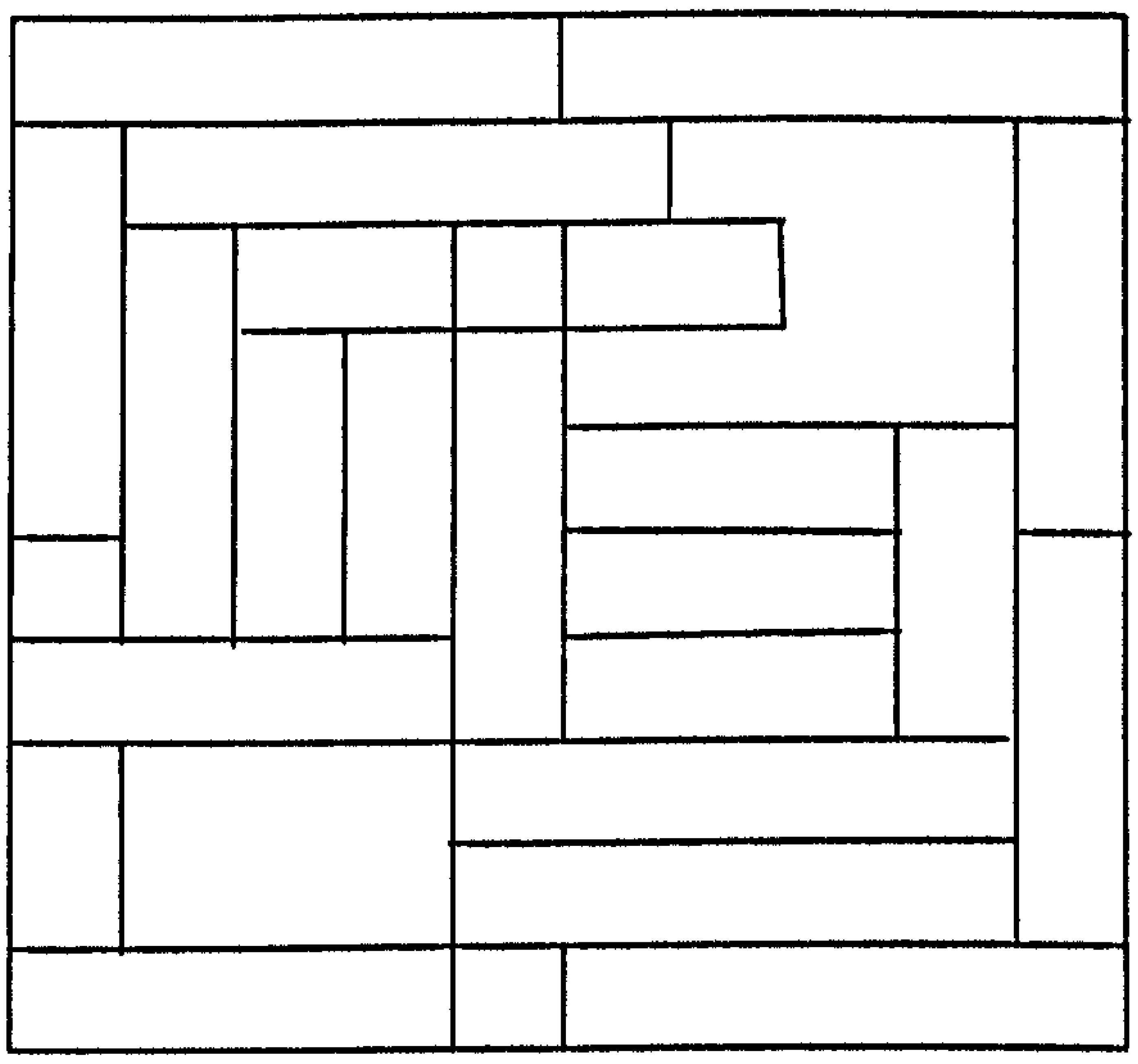
YOU ARE ALLOWED ONLY 20 MINUTES TO ANSWER ALL THE ITEMS.
TRY TO ANSWER EVERY ITEM, BUT DON'T WORRY IF YOU CAN'T.
DO AS MUCH AS YOU CAN IN THE TIME ALLOWED.
DON'T SPEND TOO MUCH TIME ON ANY ONE ITEM

DO NOT START UNTIL YOU ARE TOLD TO DO SO

LOOKING FOR HIDDEN SHAPES

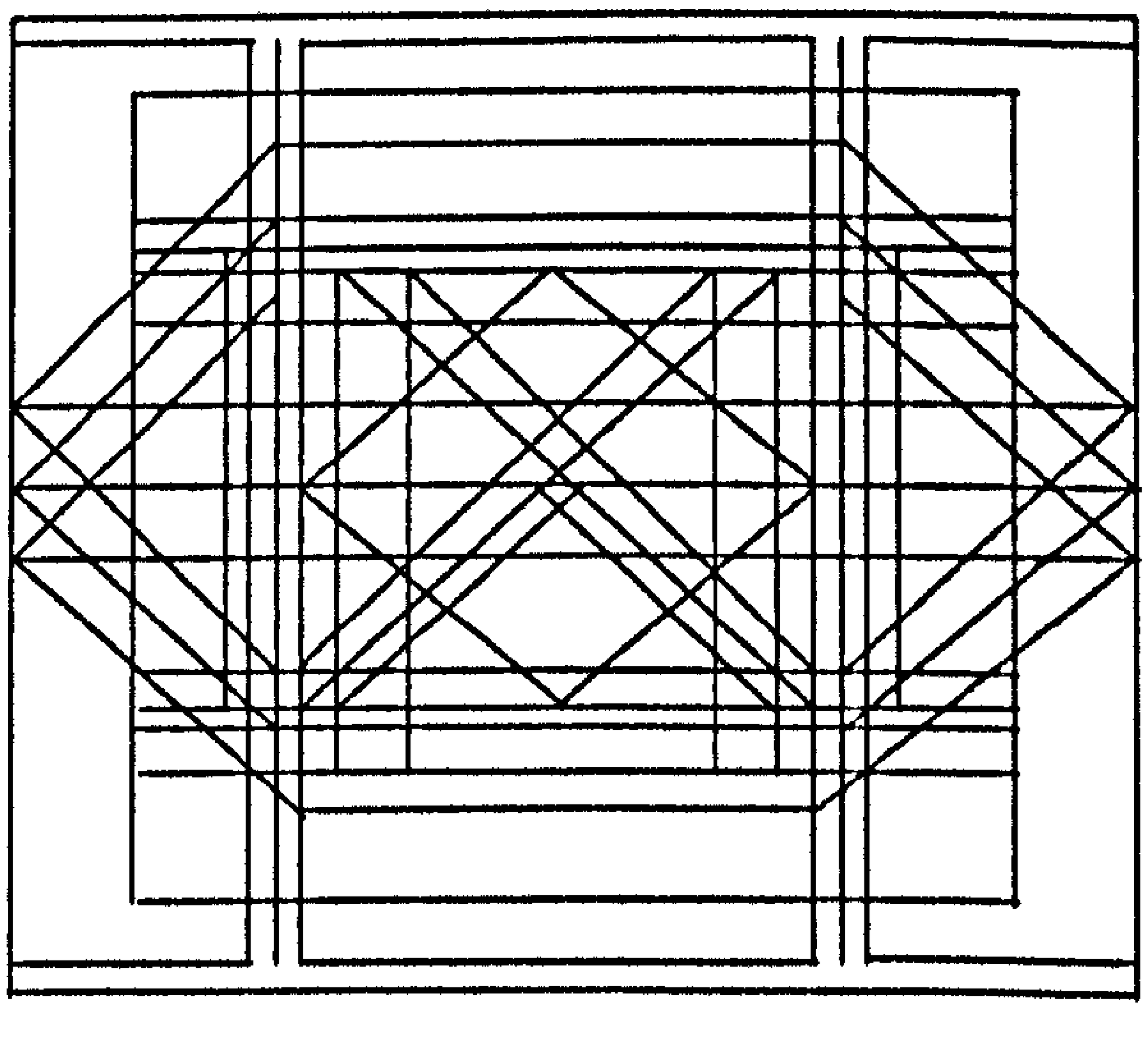
A simple geometric figure can be 'hidden' by embedding it in a complex pattern of lines. For example, the simple L-shaped figure on the left has been hidden in the pattern of lines on the right. Can you pick it out?





Using a pen, trace round the outline of the L- shaped figure to mark the position.

The same L-shaped figure is also hidden within the more complex pattern below. It is the same size, the same shape and faces in the same direction as when it appears alone. Mark its position by tracing round its outline using a pen.



(To check your answers, see page 14)

More problems of this type appear on the following pages. In each case, you are required to find a simple shape 'hidden' within a complex pattern of lines, and then, using a pen, to record the shape's position by tracing its outline.

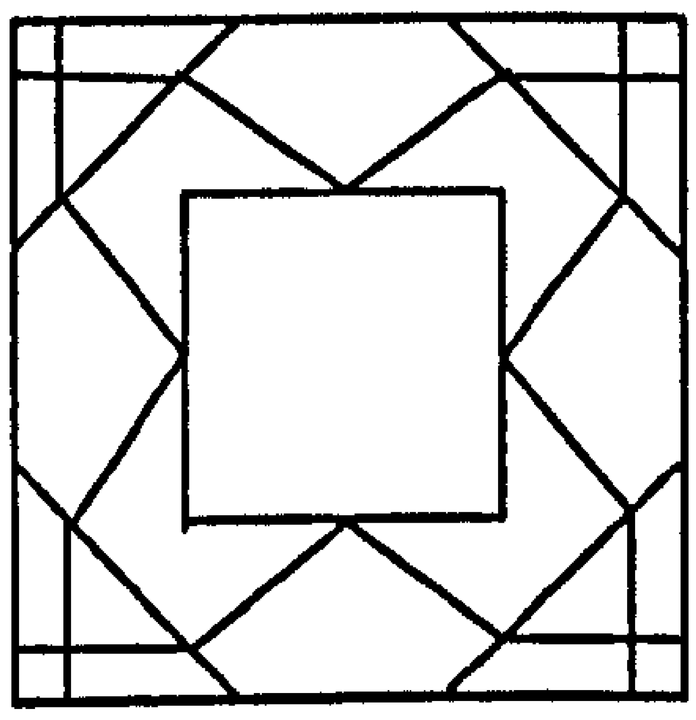
There are TWO patterns on each page. Below each pattern there is a code letter (A, or B, or C etc.) to identify which shape is hidden in that pattern.

In the last page of this booklet, you will see all the shapes you have to find, along with their corresponding code letters. Keep this page opened out until you have finished all the problems.

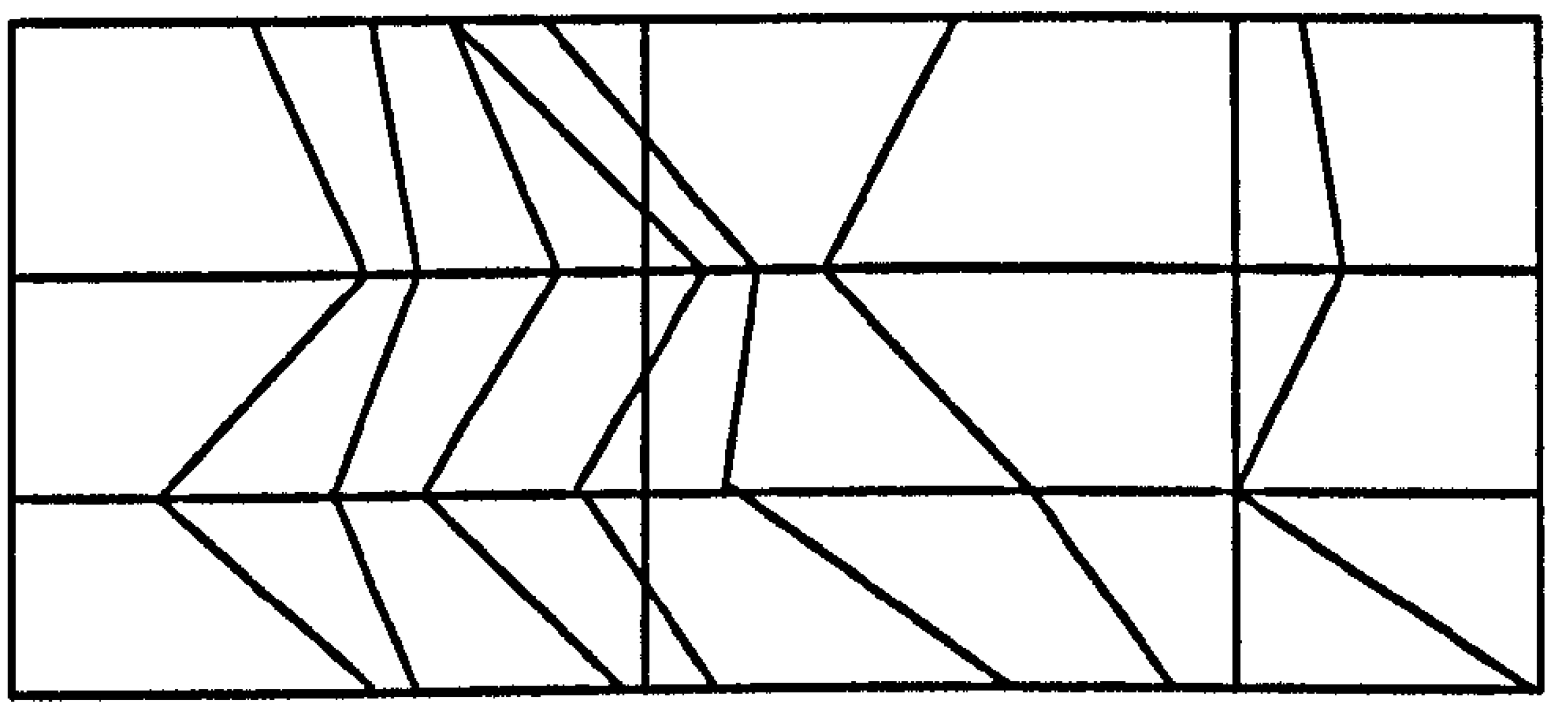
Note these points:

1. **You can refer to the page of simple shapes as often as necessary.**
2. **When it appears within a complex pattern, the required shape is always:**
   - **the same size,**
   - **has the same proportion,**
   - **and faces in the same direction as when it appears alone**
3. **Within each pattern, the shape you have to find appears only once.**
4. **Trace the required shape and only that shape for each problem.**
5. **Do the problems in order – don't skip one unless you are absolutely stuck.**

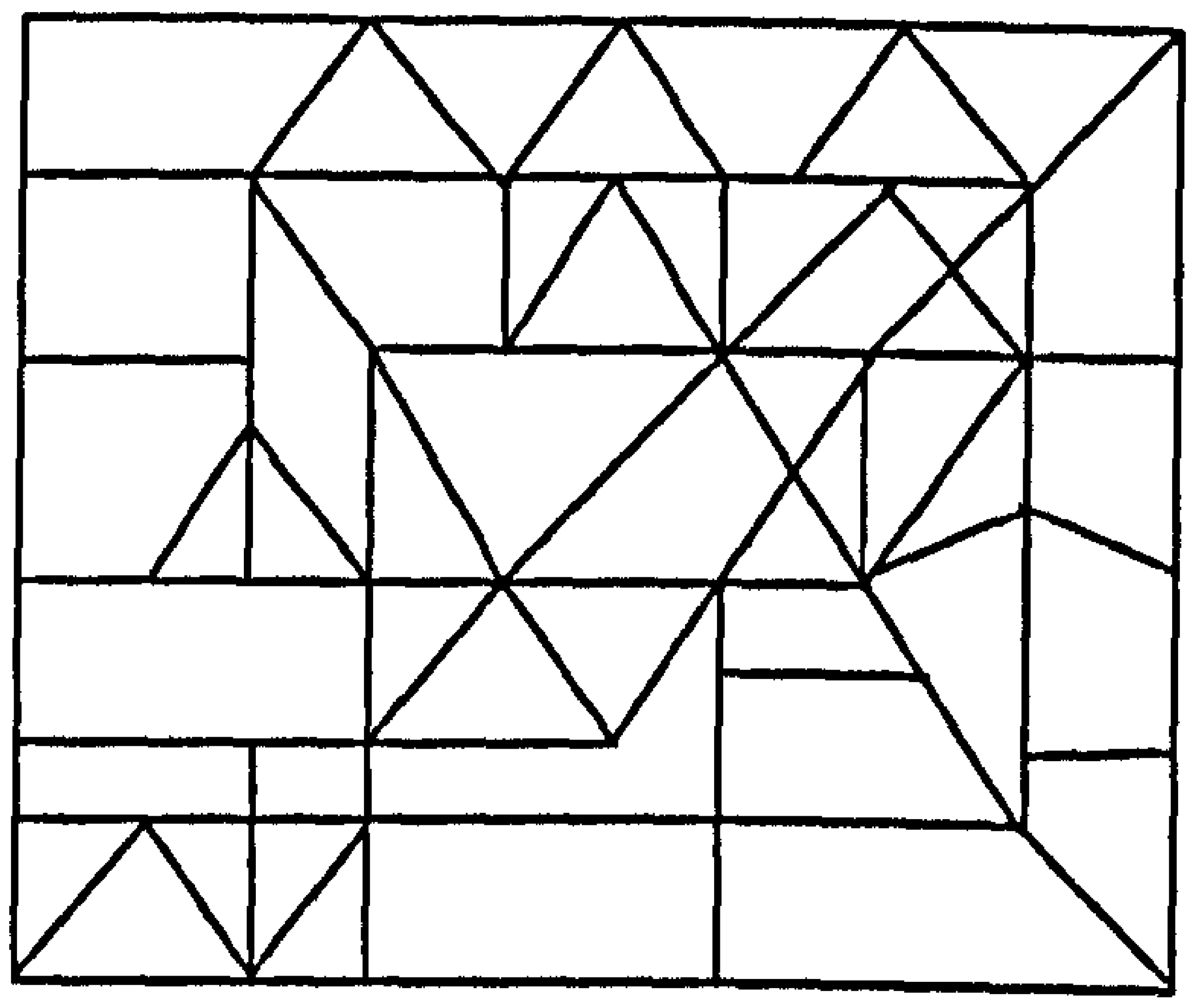
START NOW



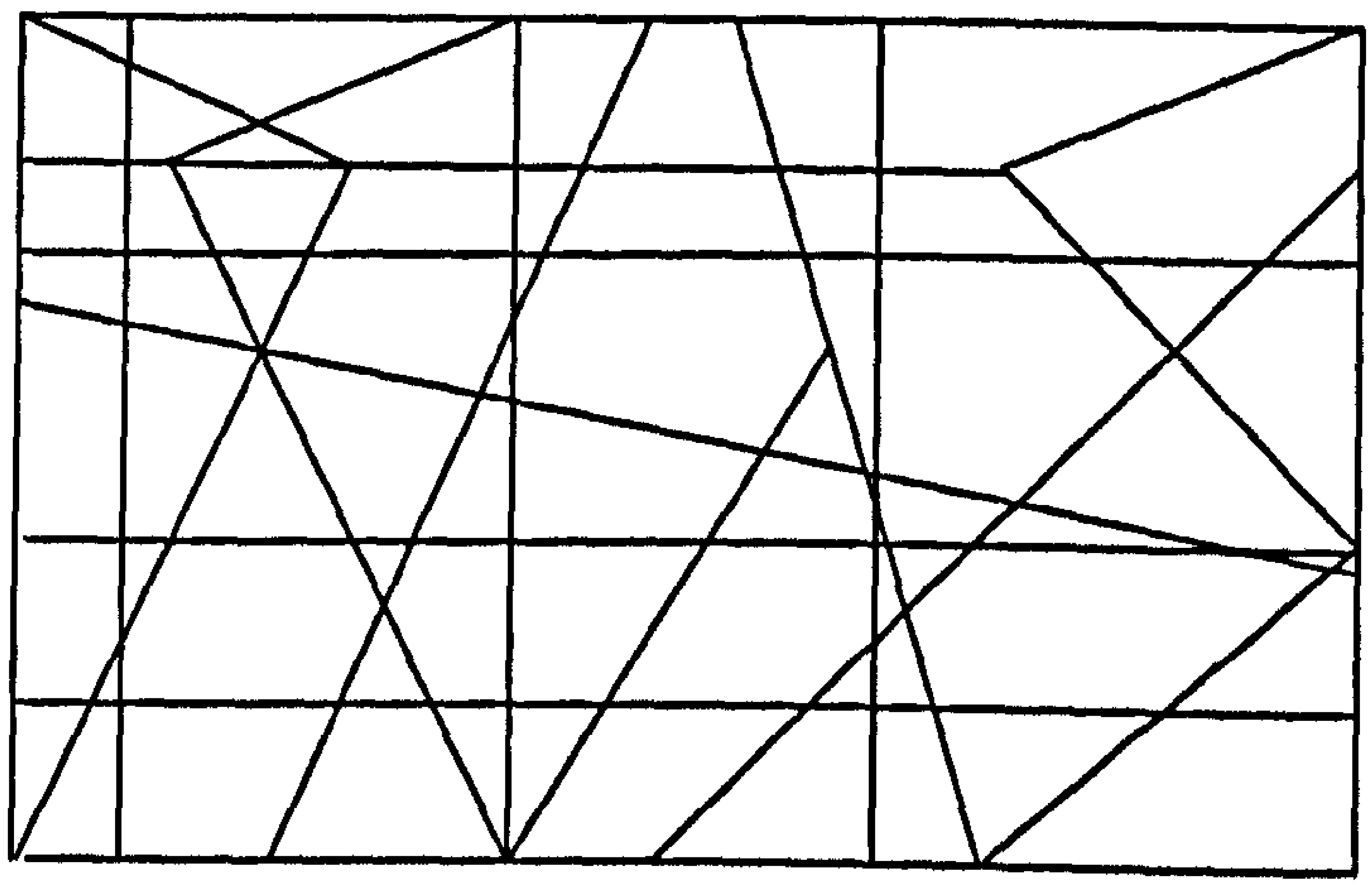
Find shape B



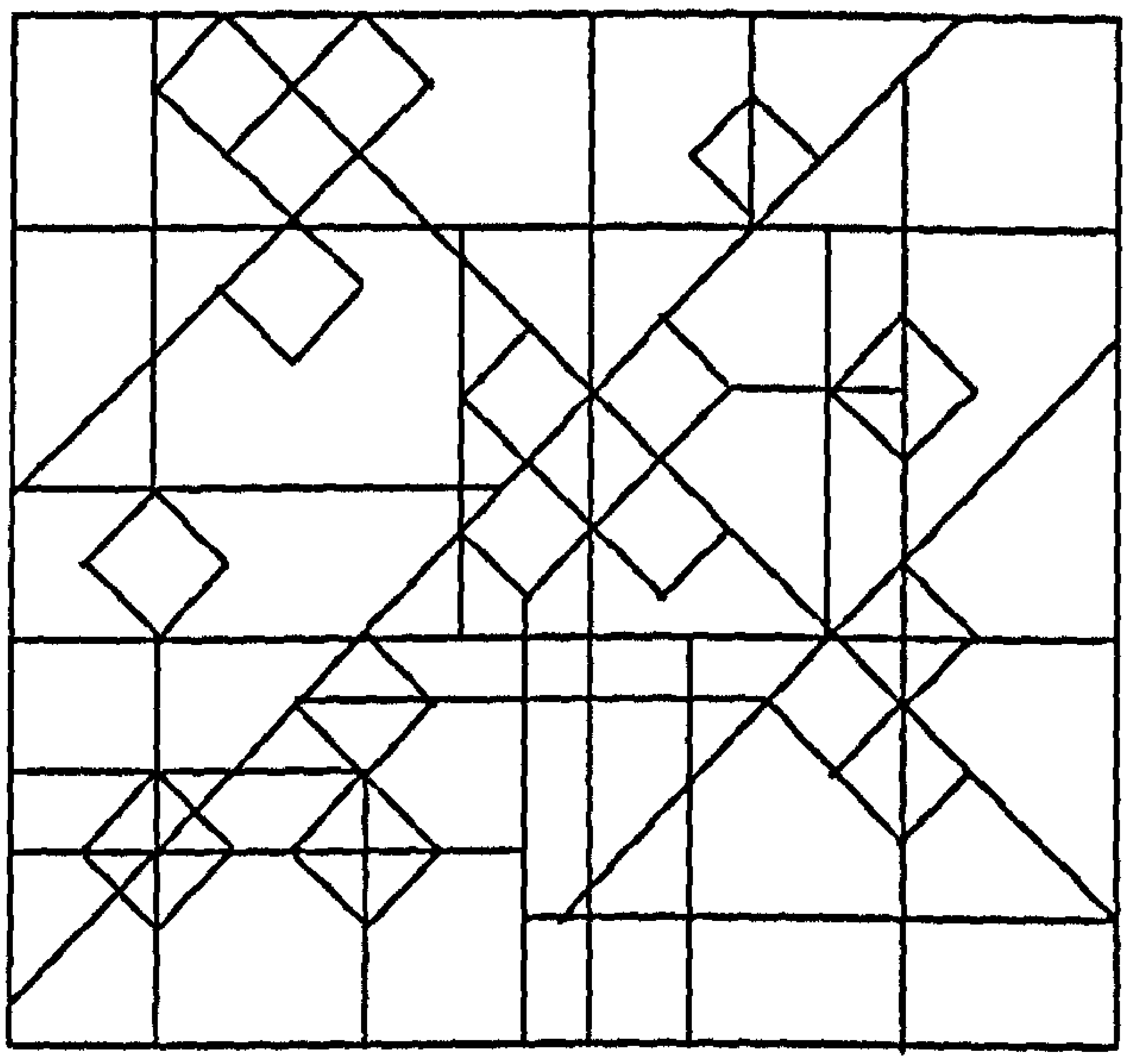
Find shape D



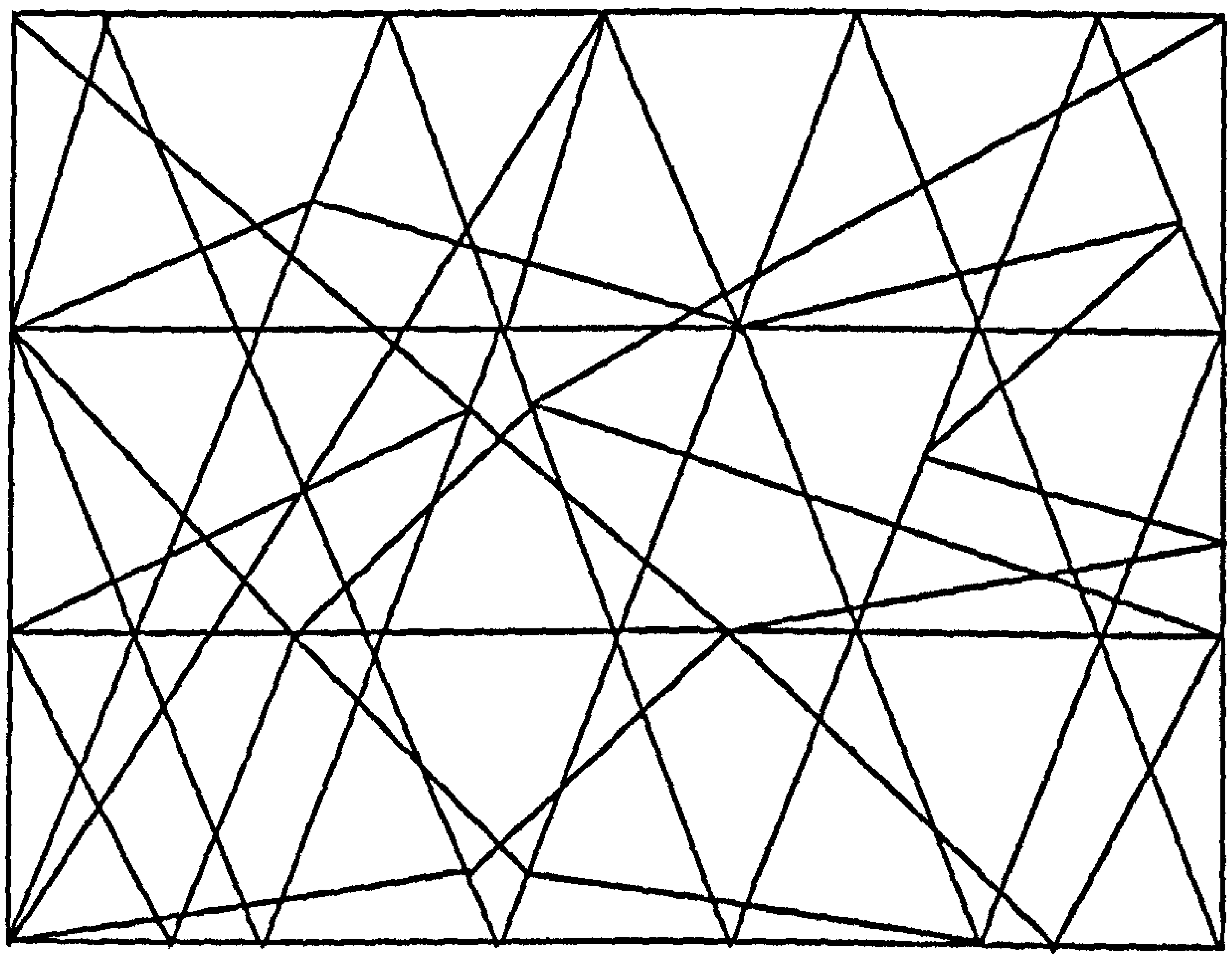
Find shape H



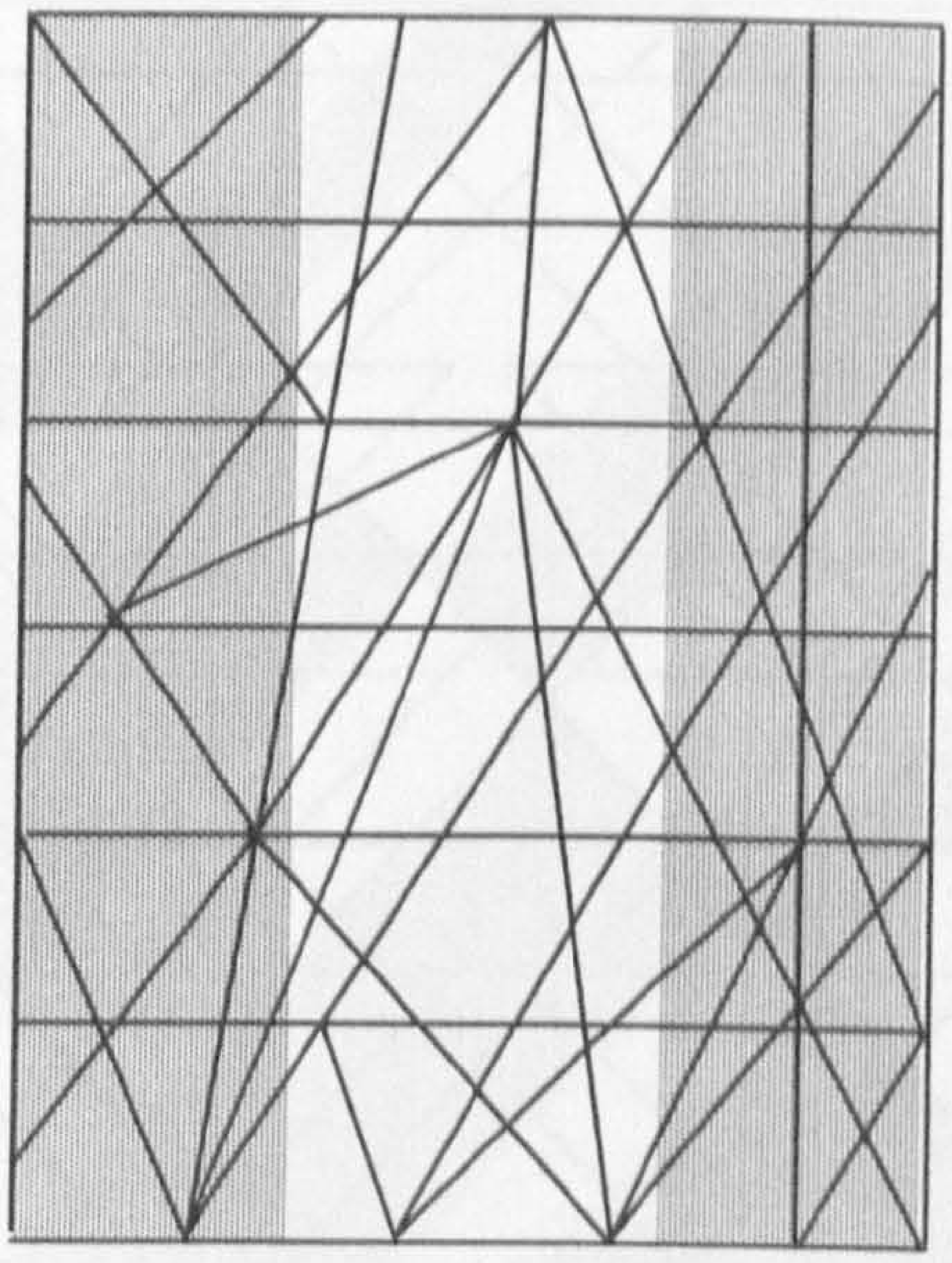
Find shape E



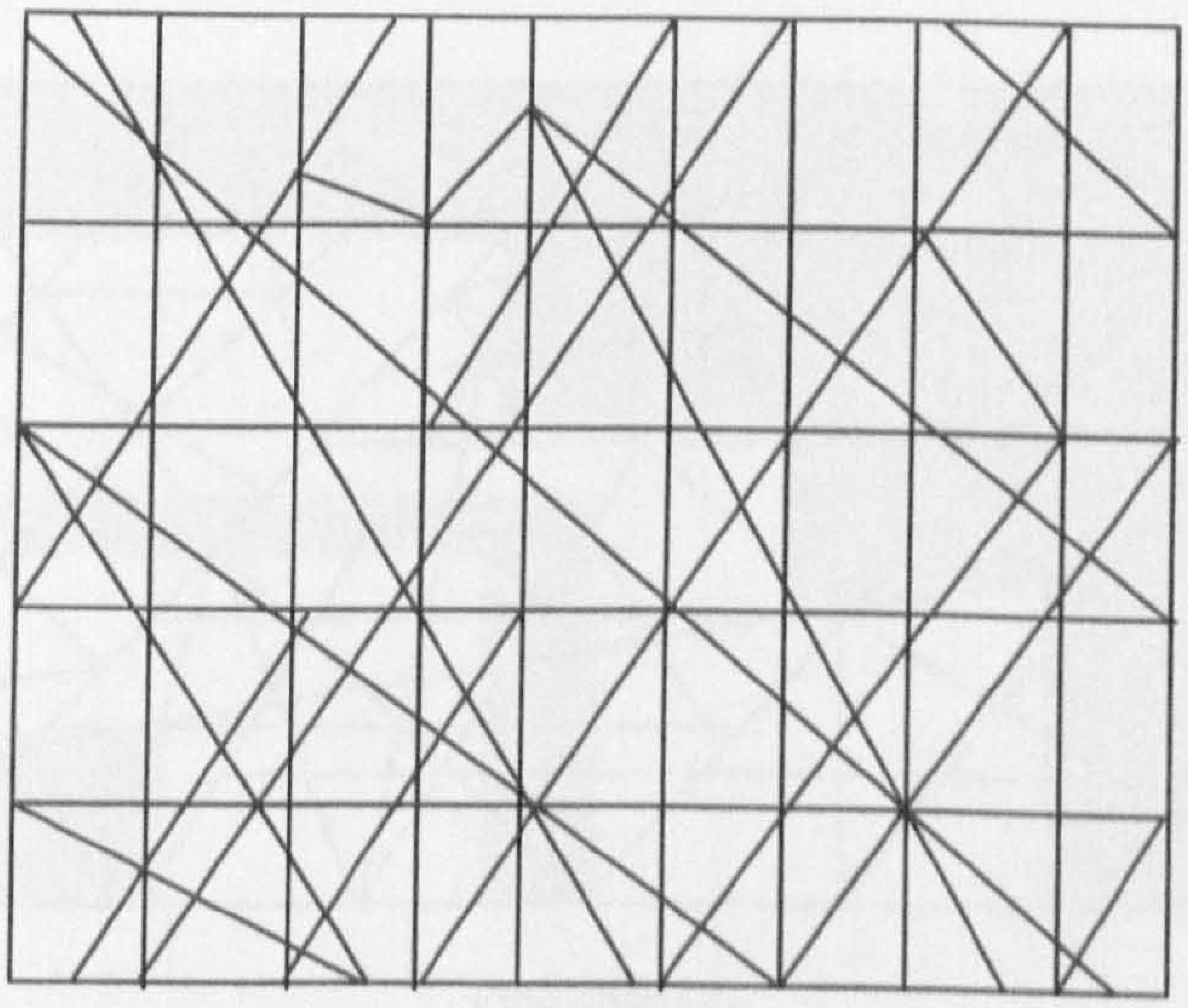
Find shape F



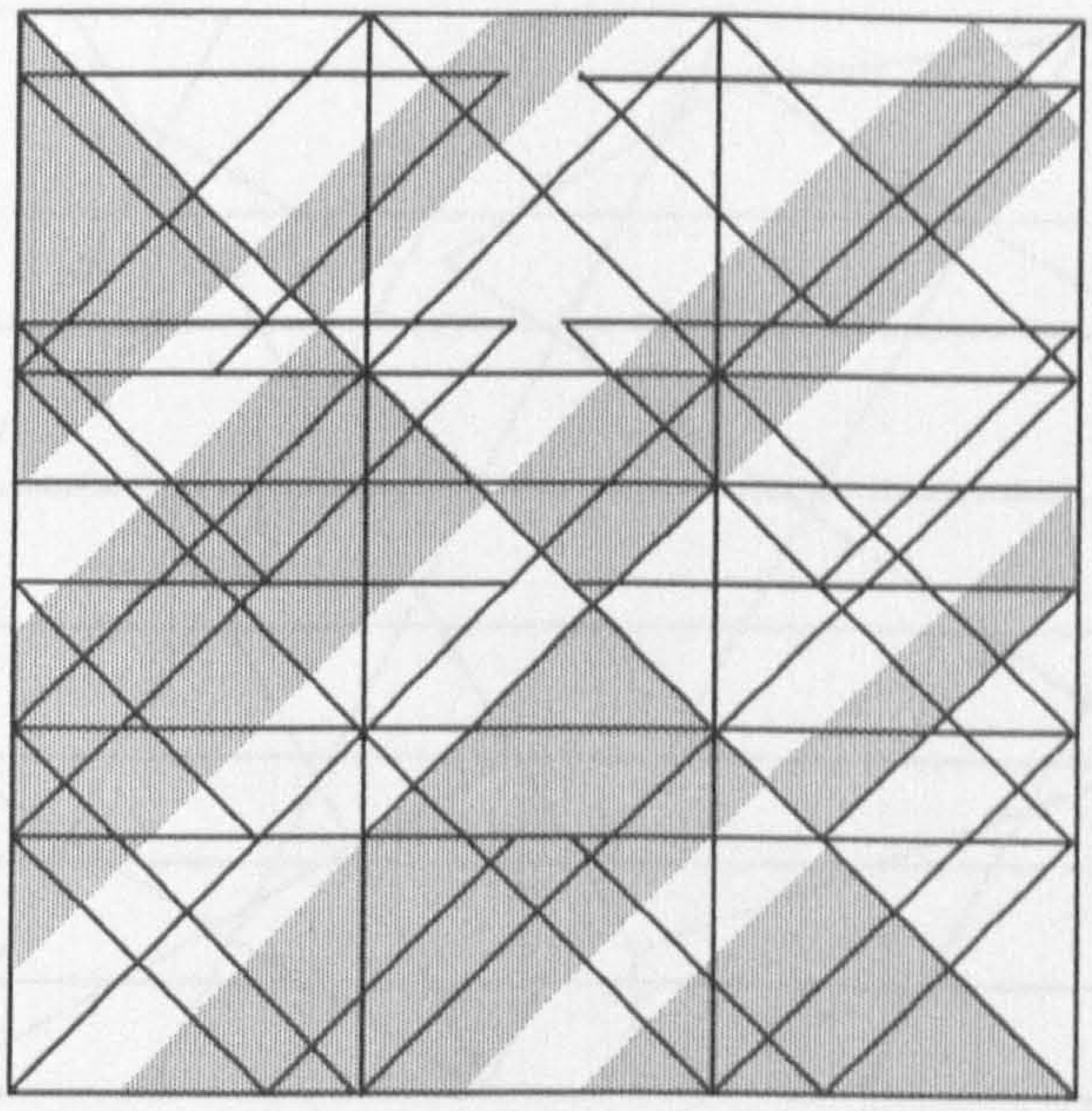
Find shape A



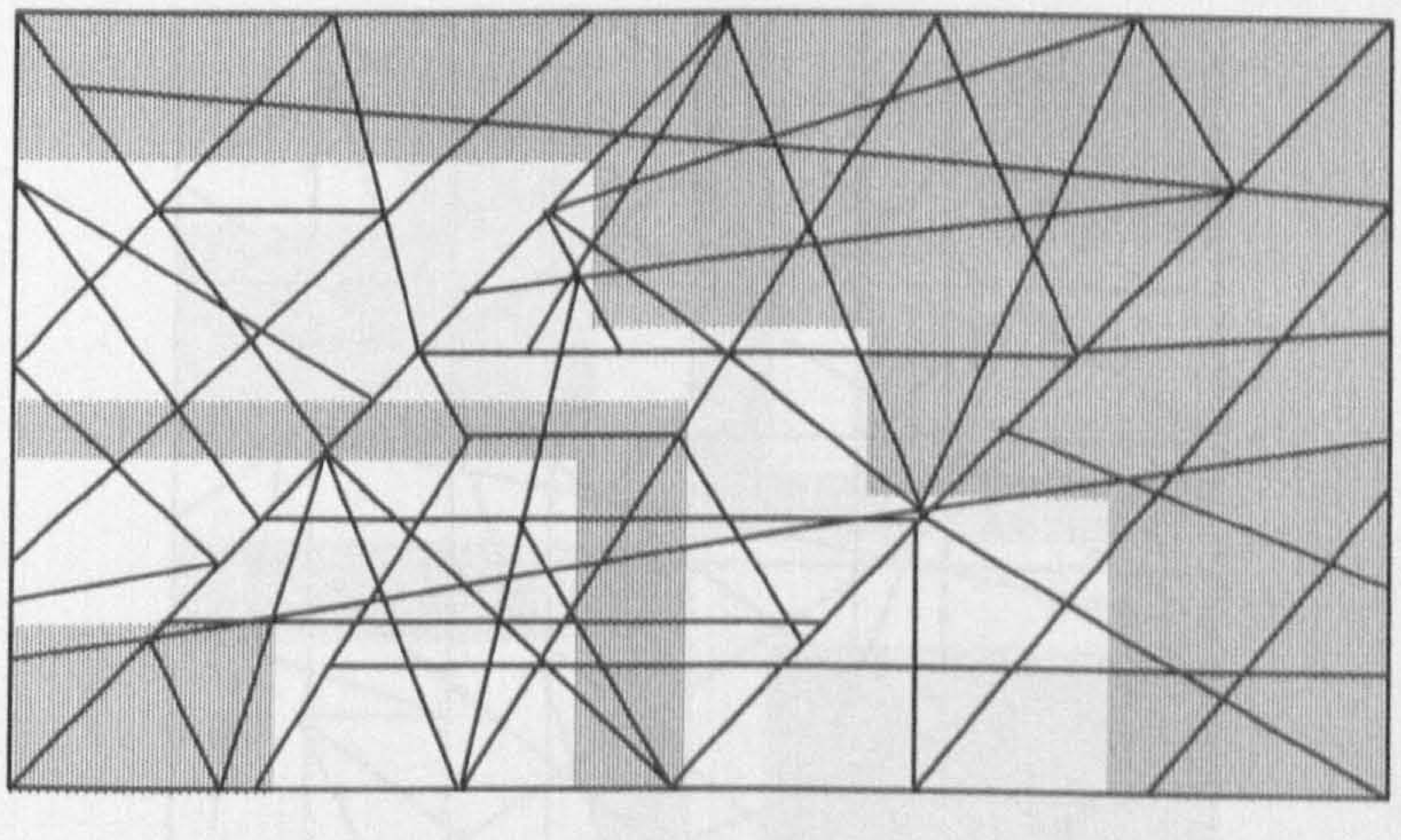
Find shape E



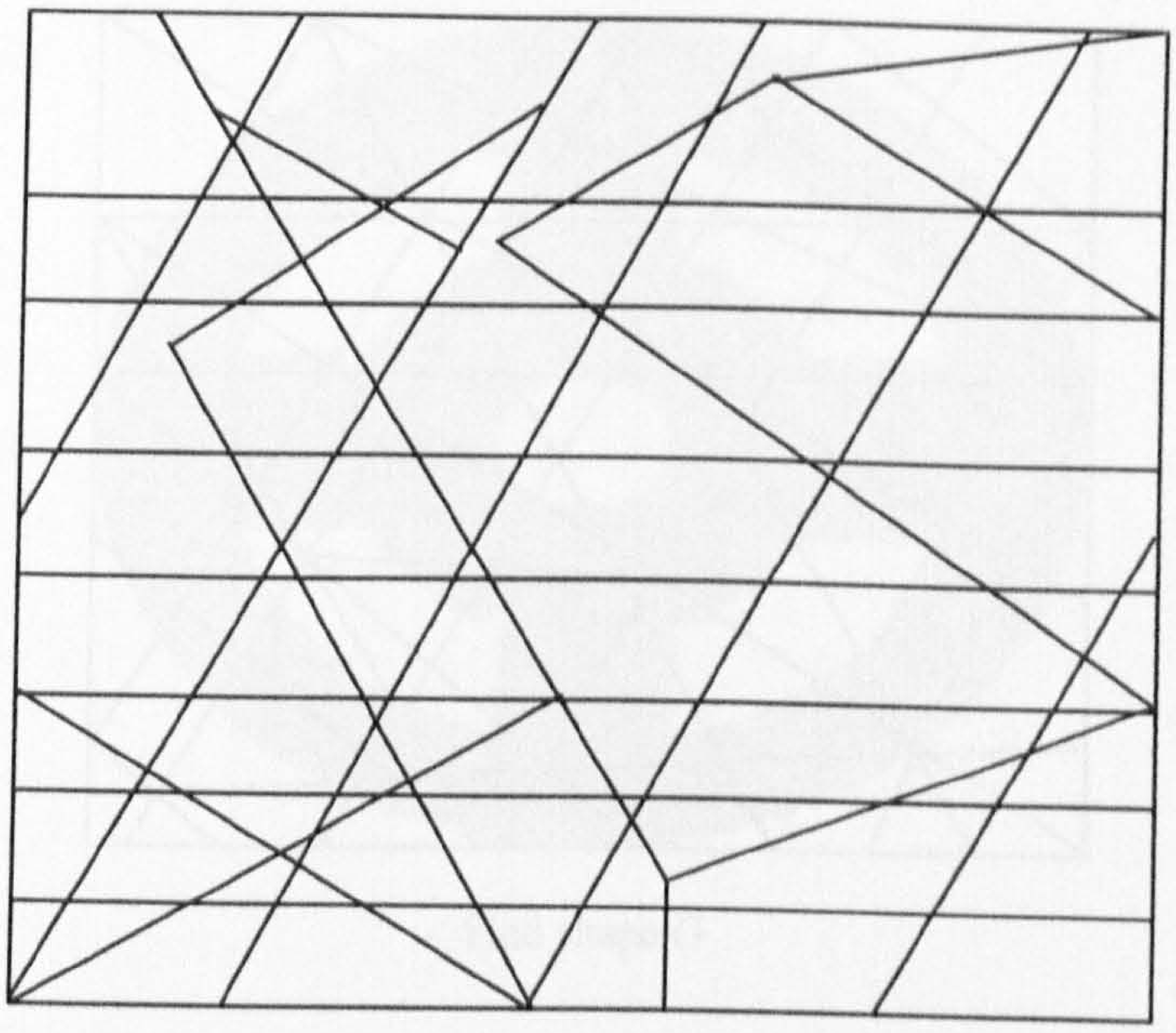
Find shape H



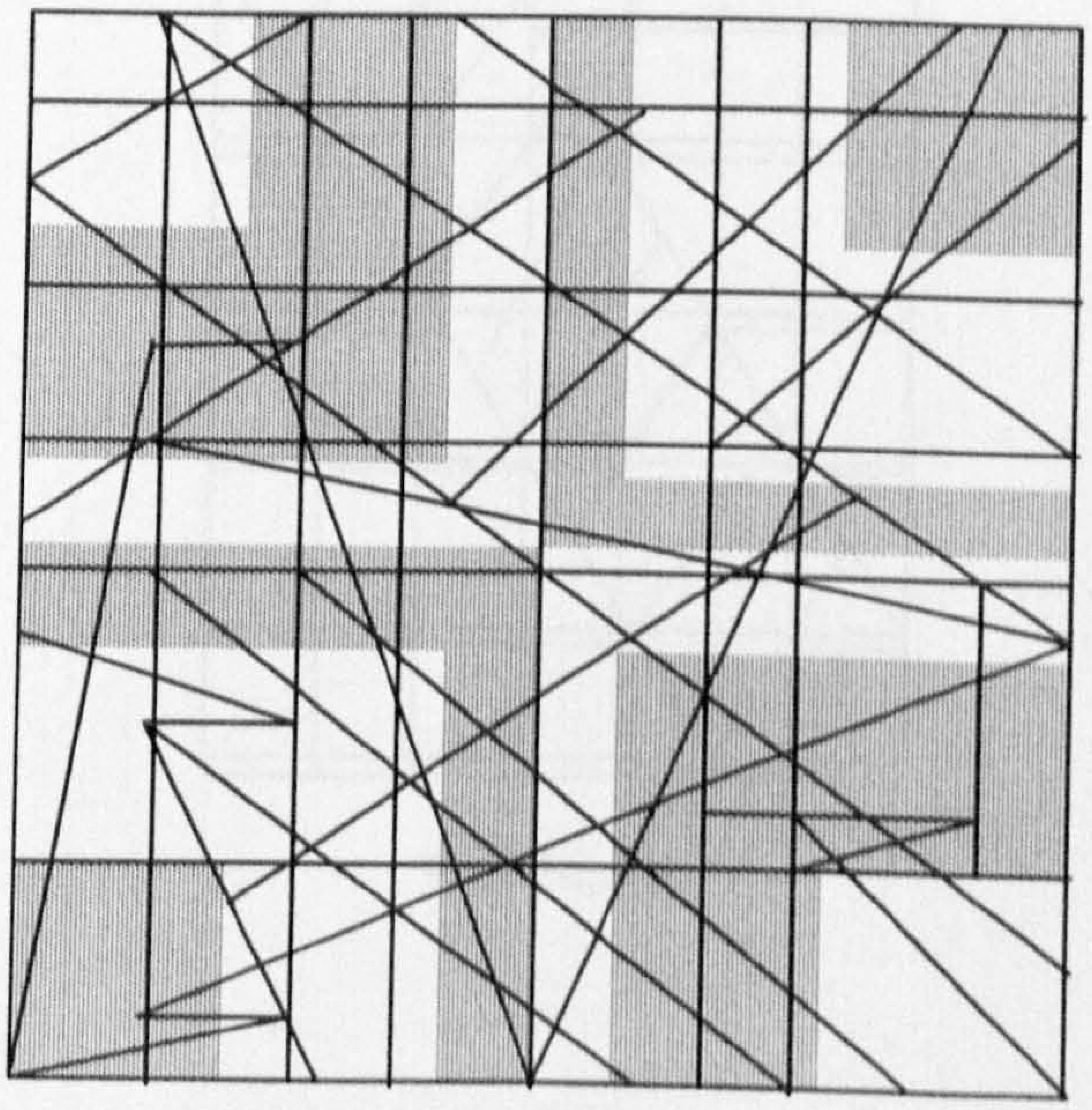
Find shape D



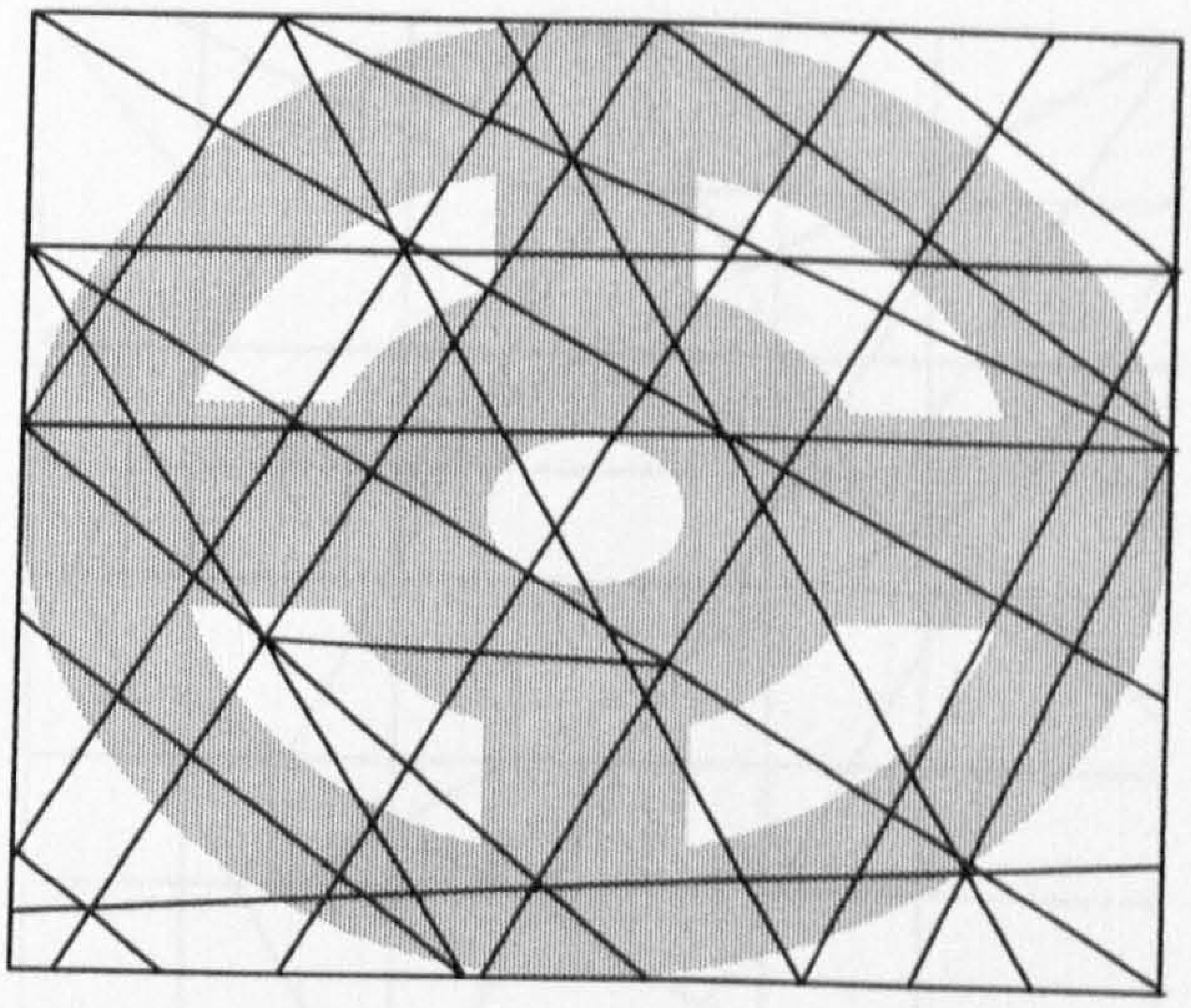
Find shape G



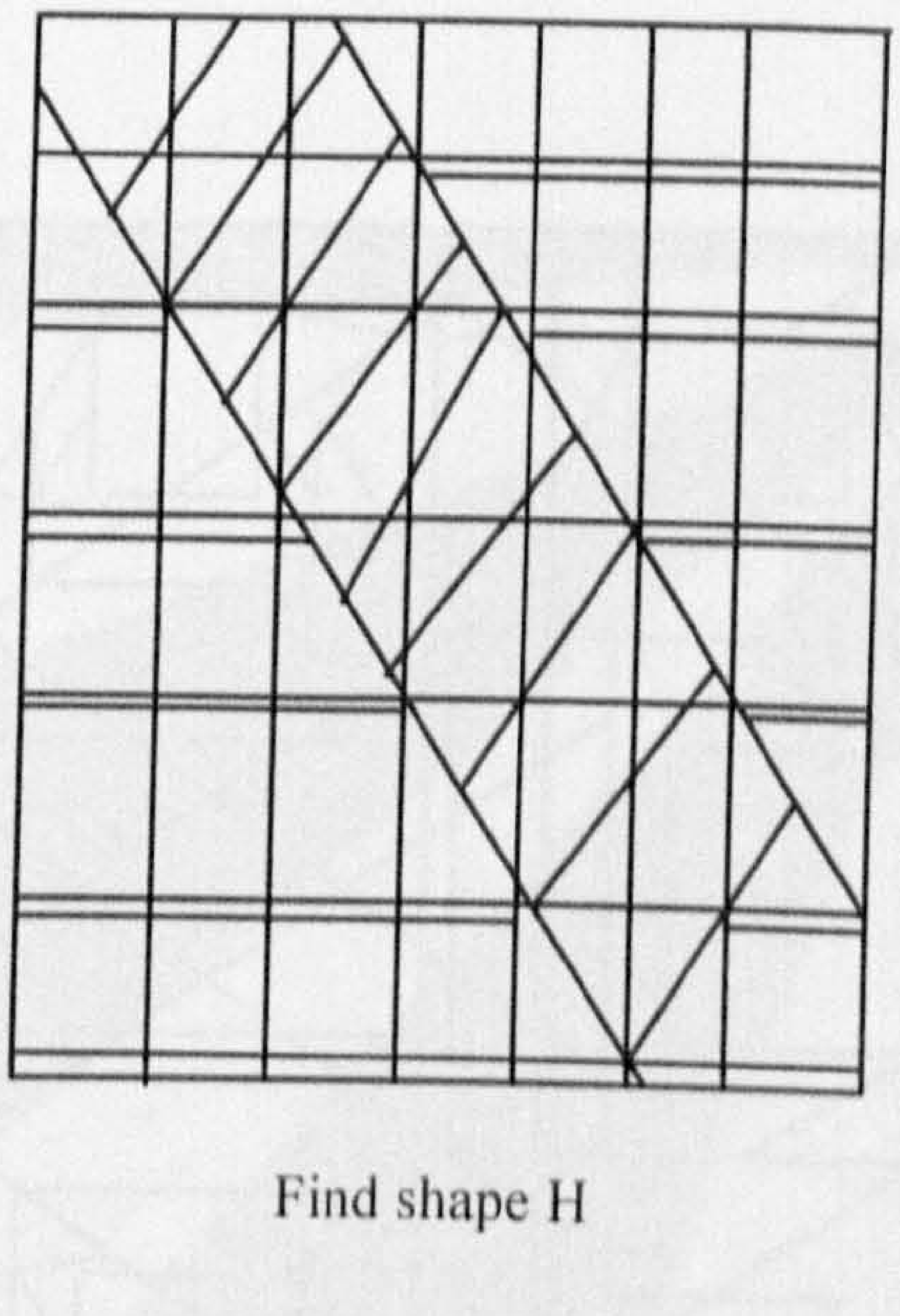
Find shape C



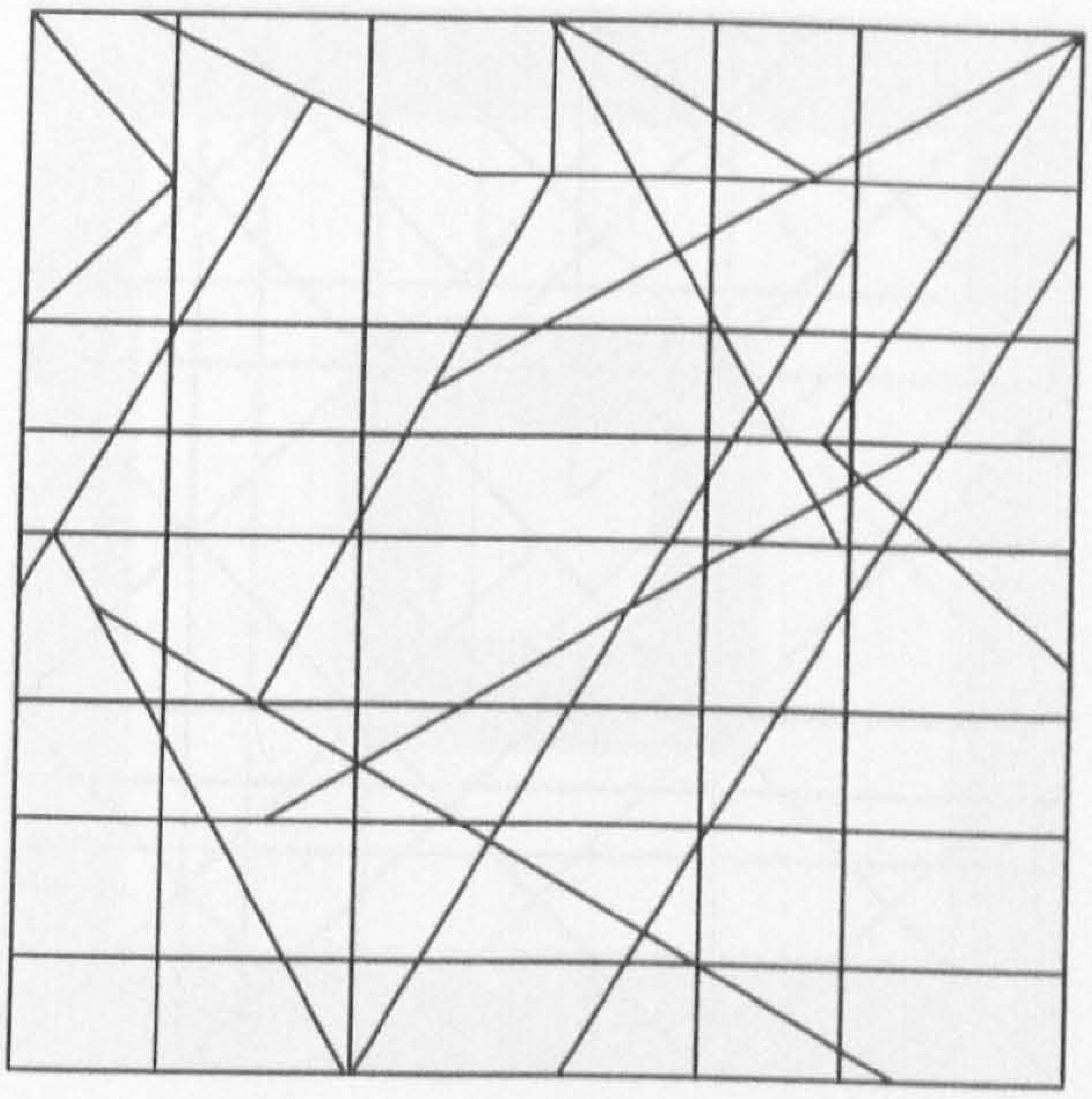
Find shape B



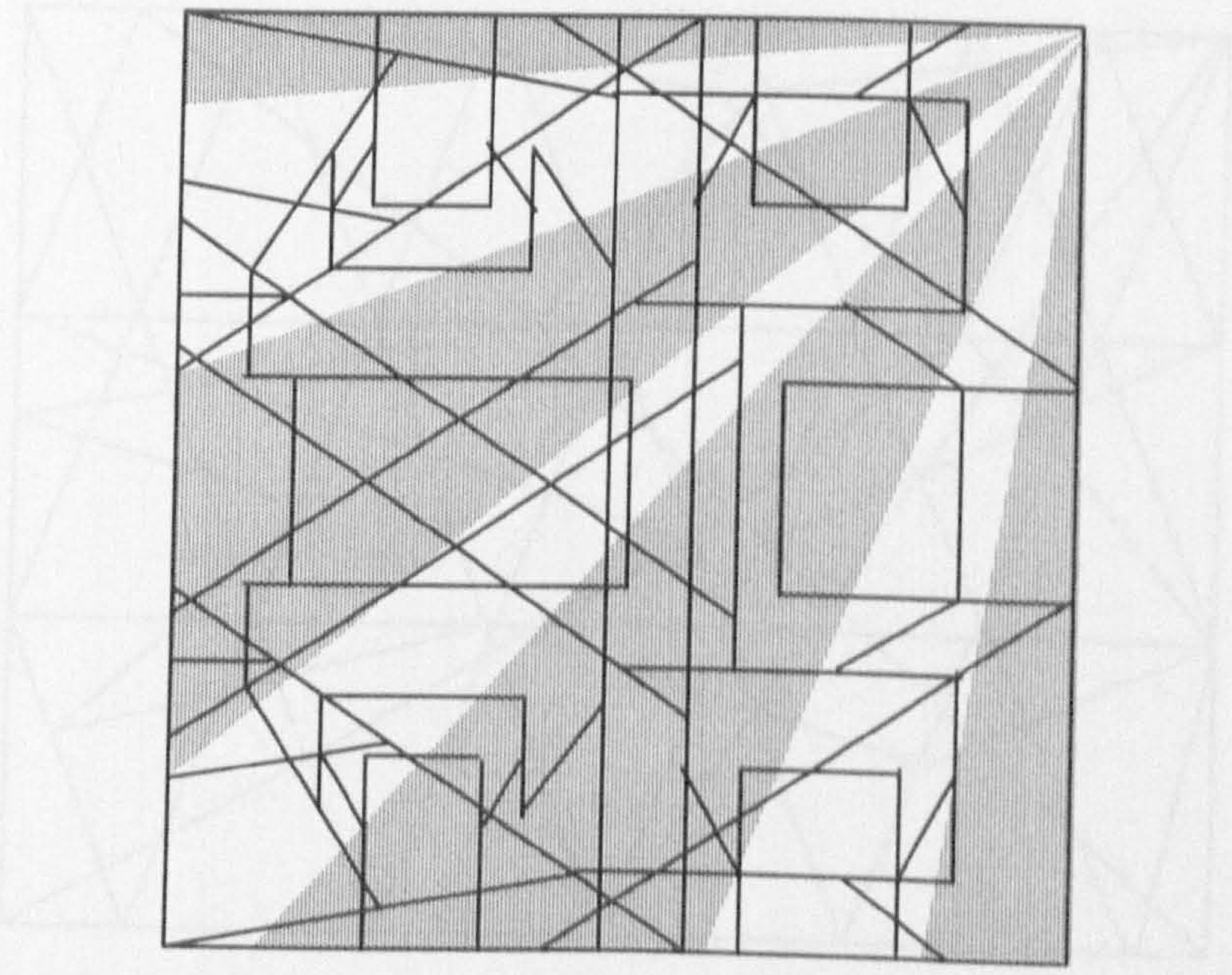
Find shape G



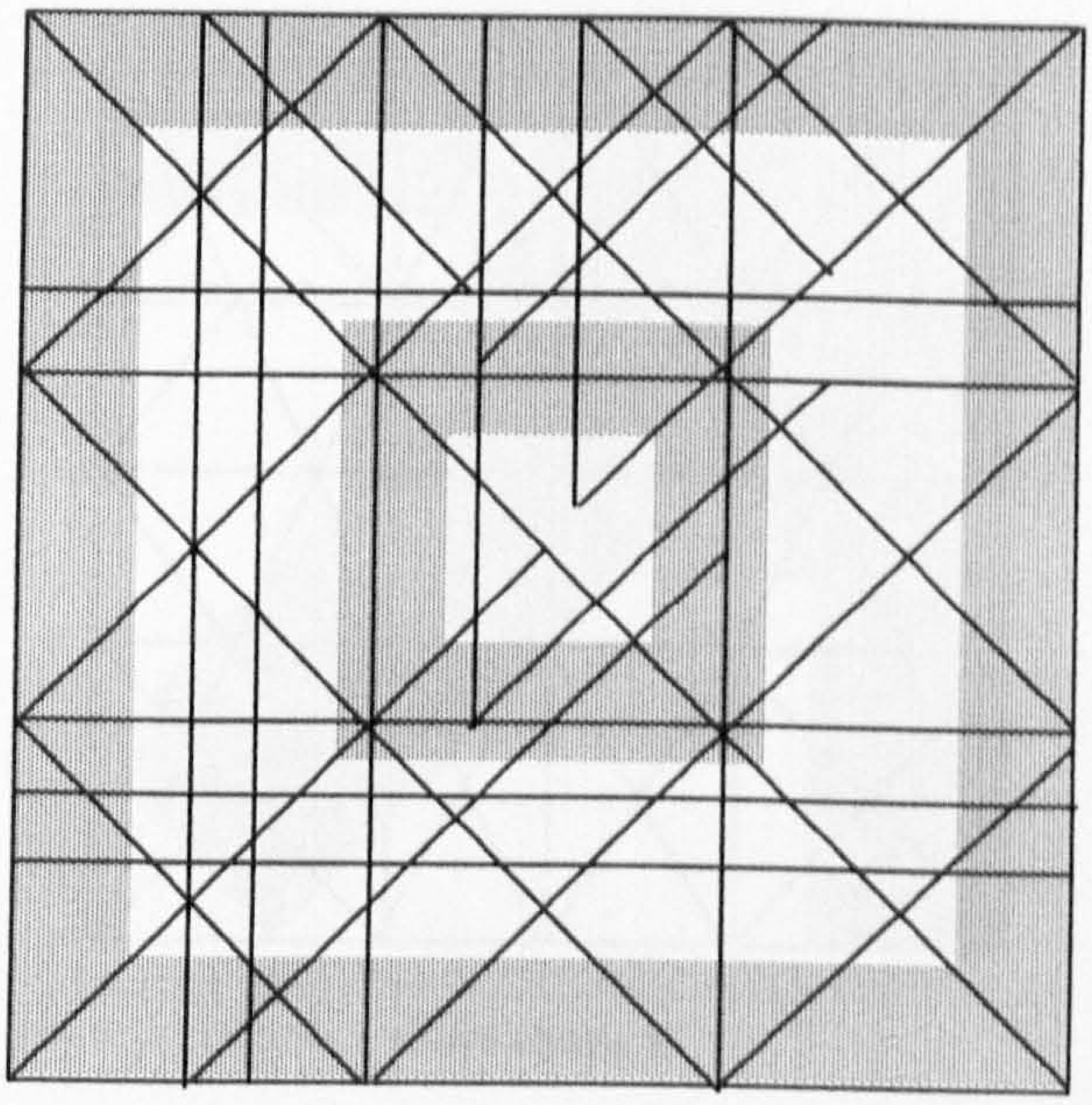
Find shape H



Find shape C



Find shape B



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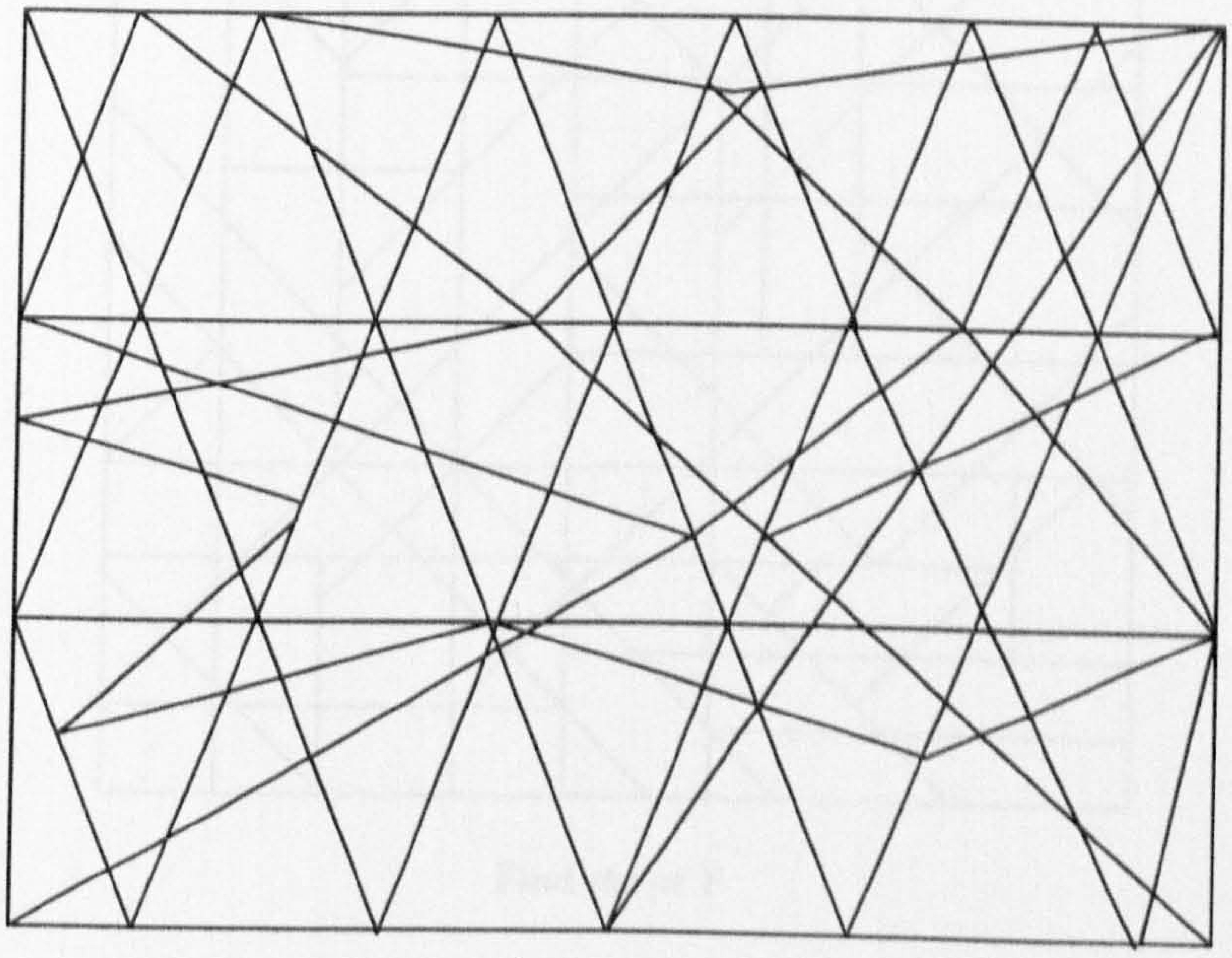
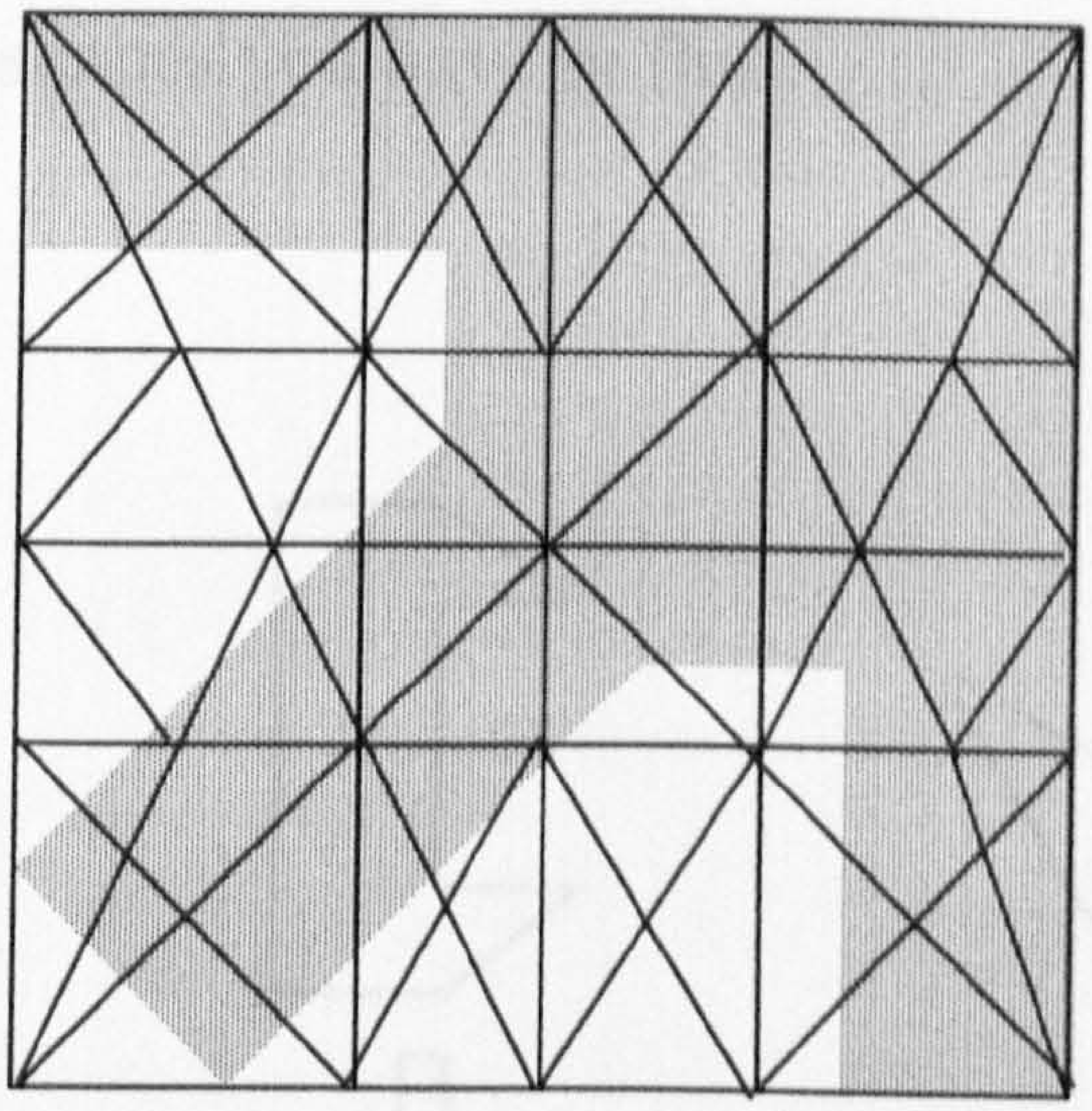
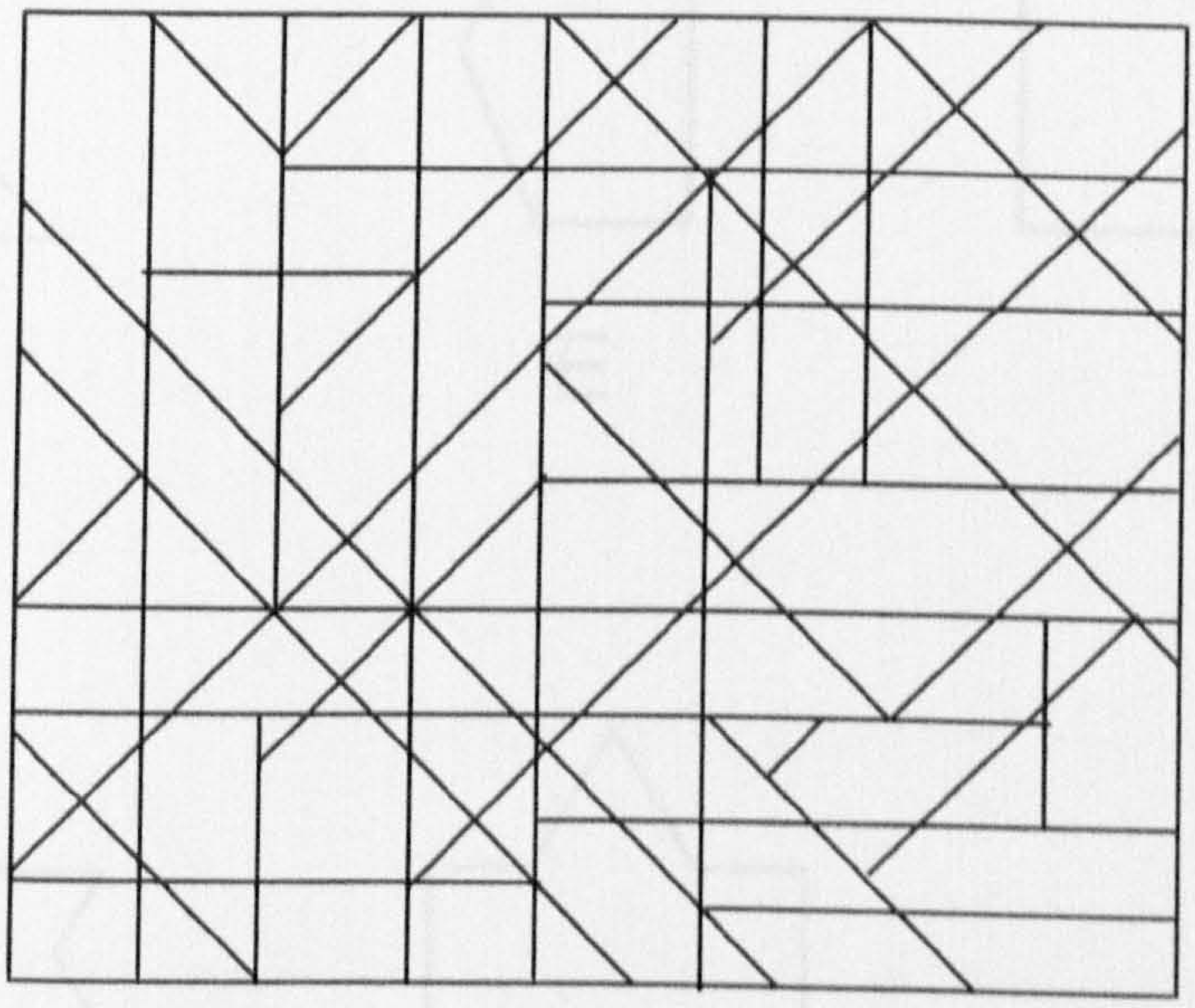


Find shape A

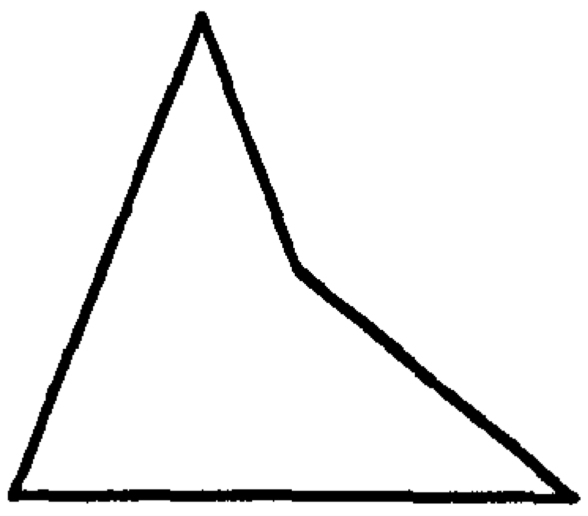


Find shape E

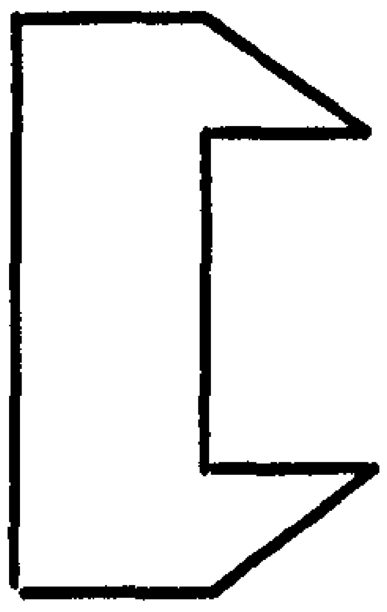


Find shape F

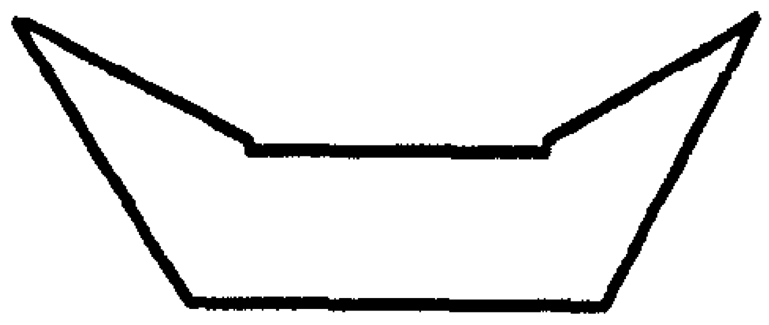
The shapes you have to find



A

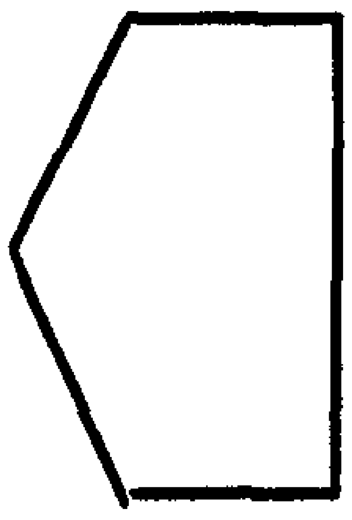


B

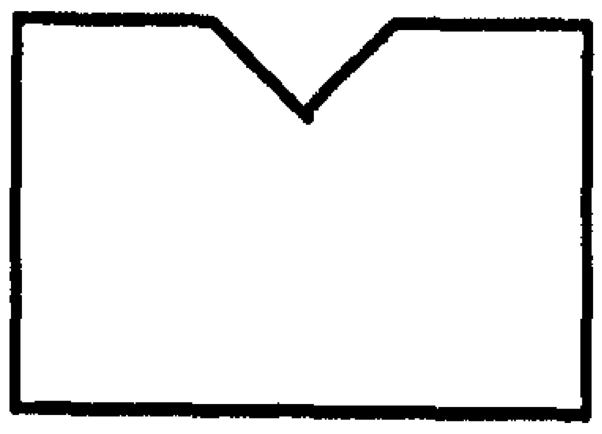


C

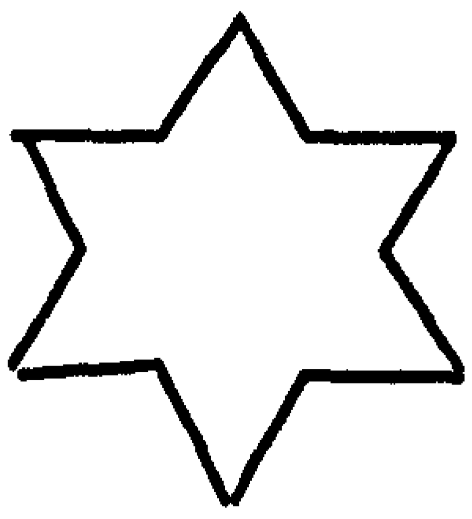
D



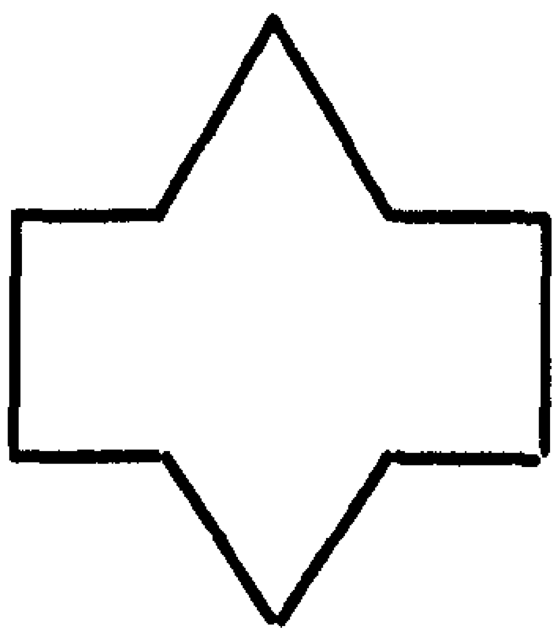
E



F

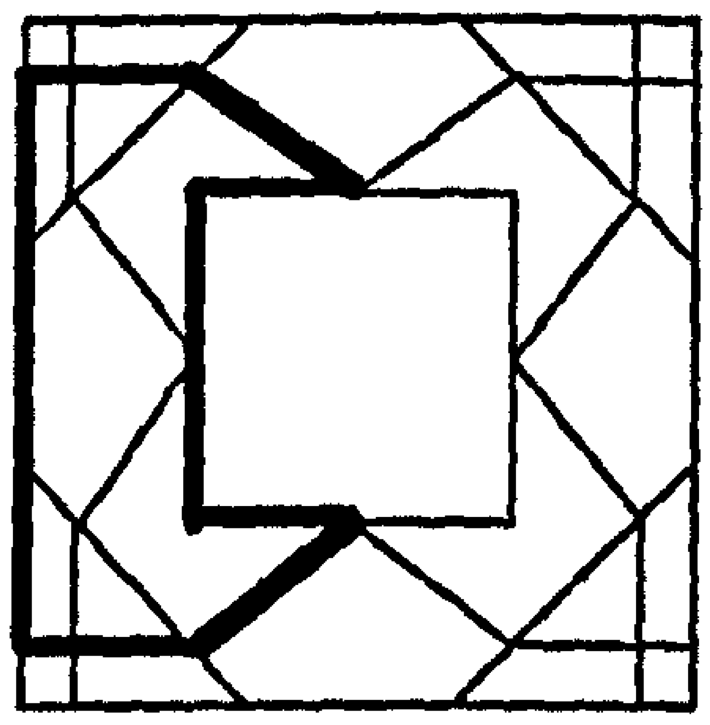


G

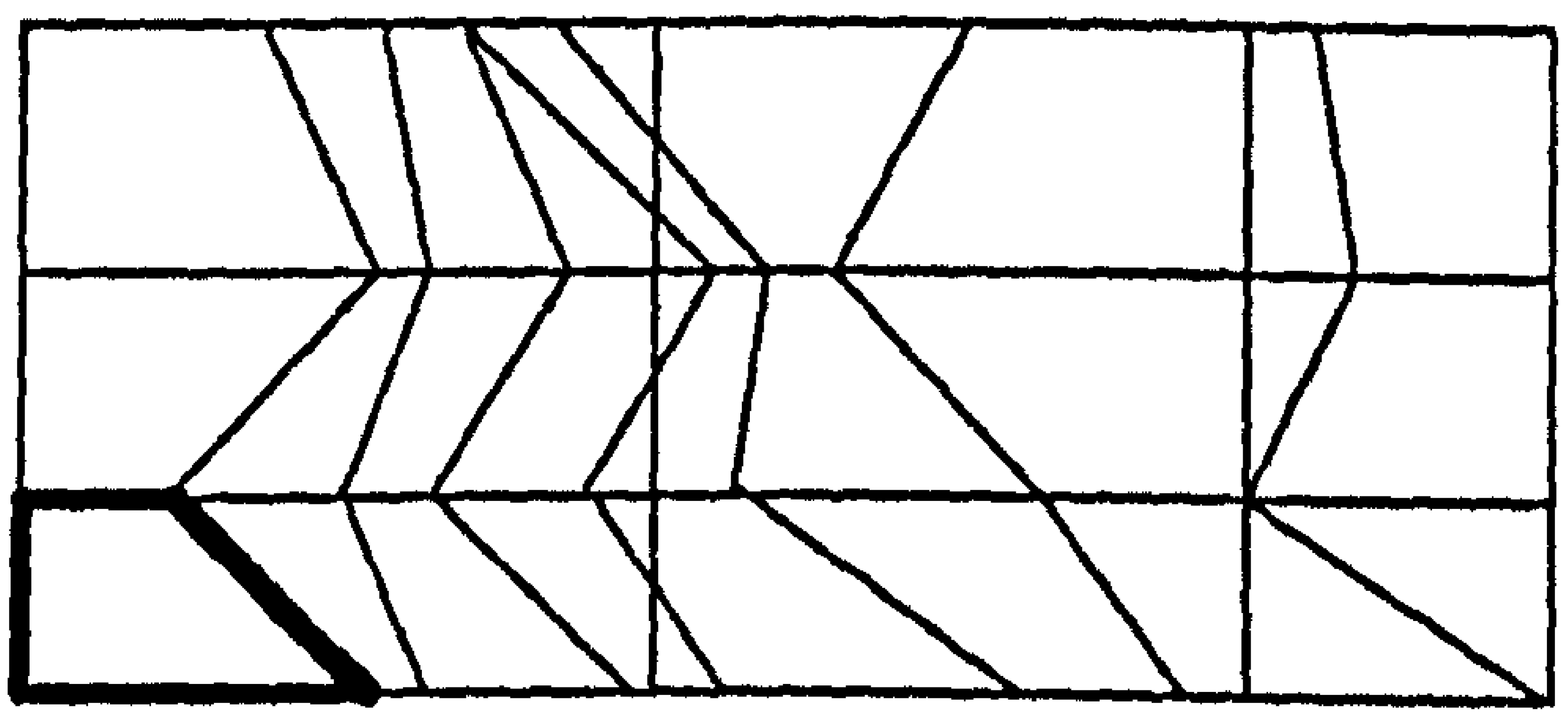


H

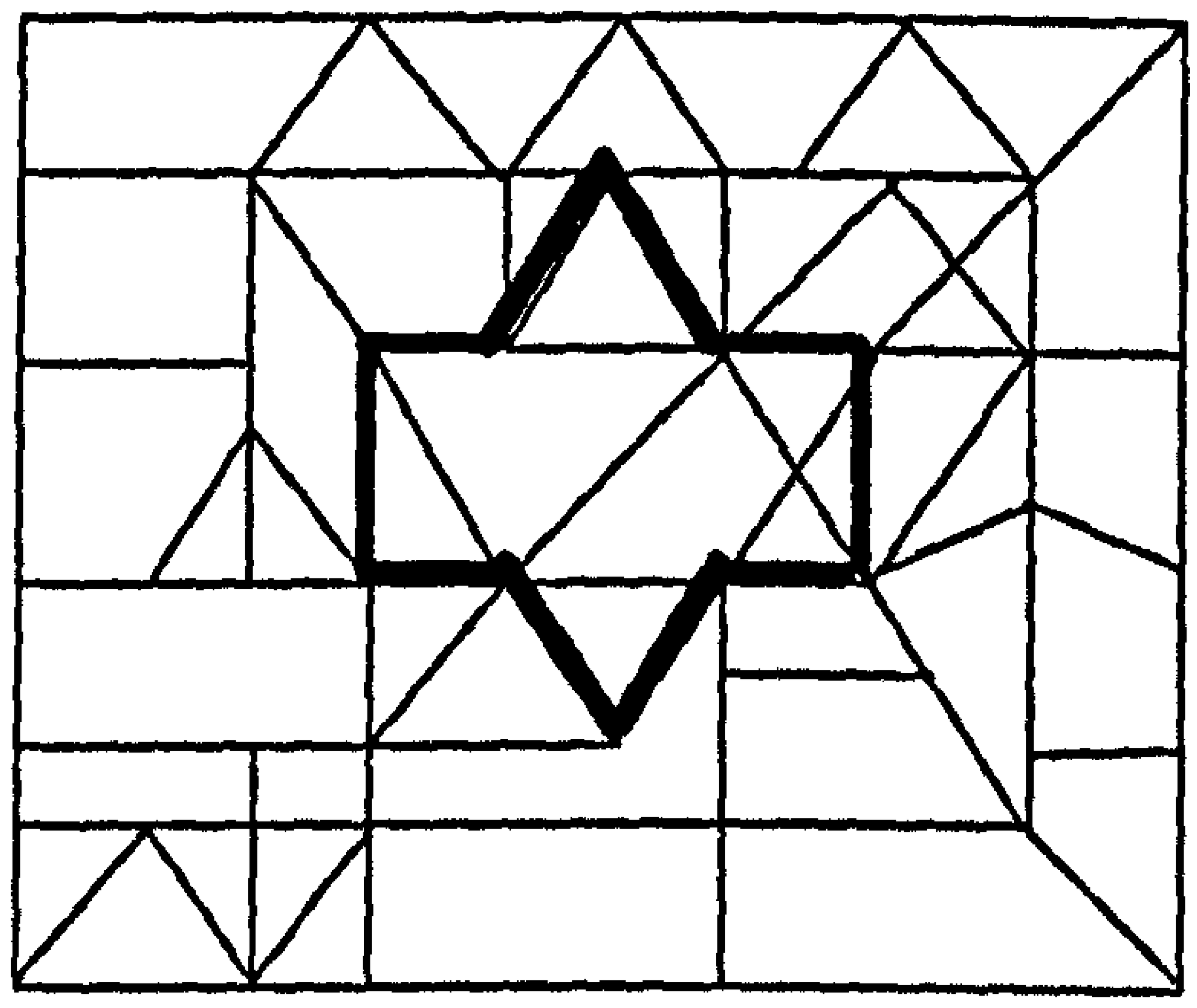
ANSWERS TO SHAPES



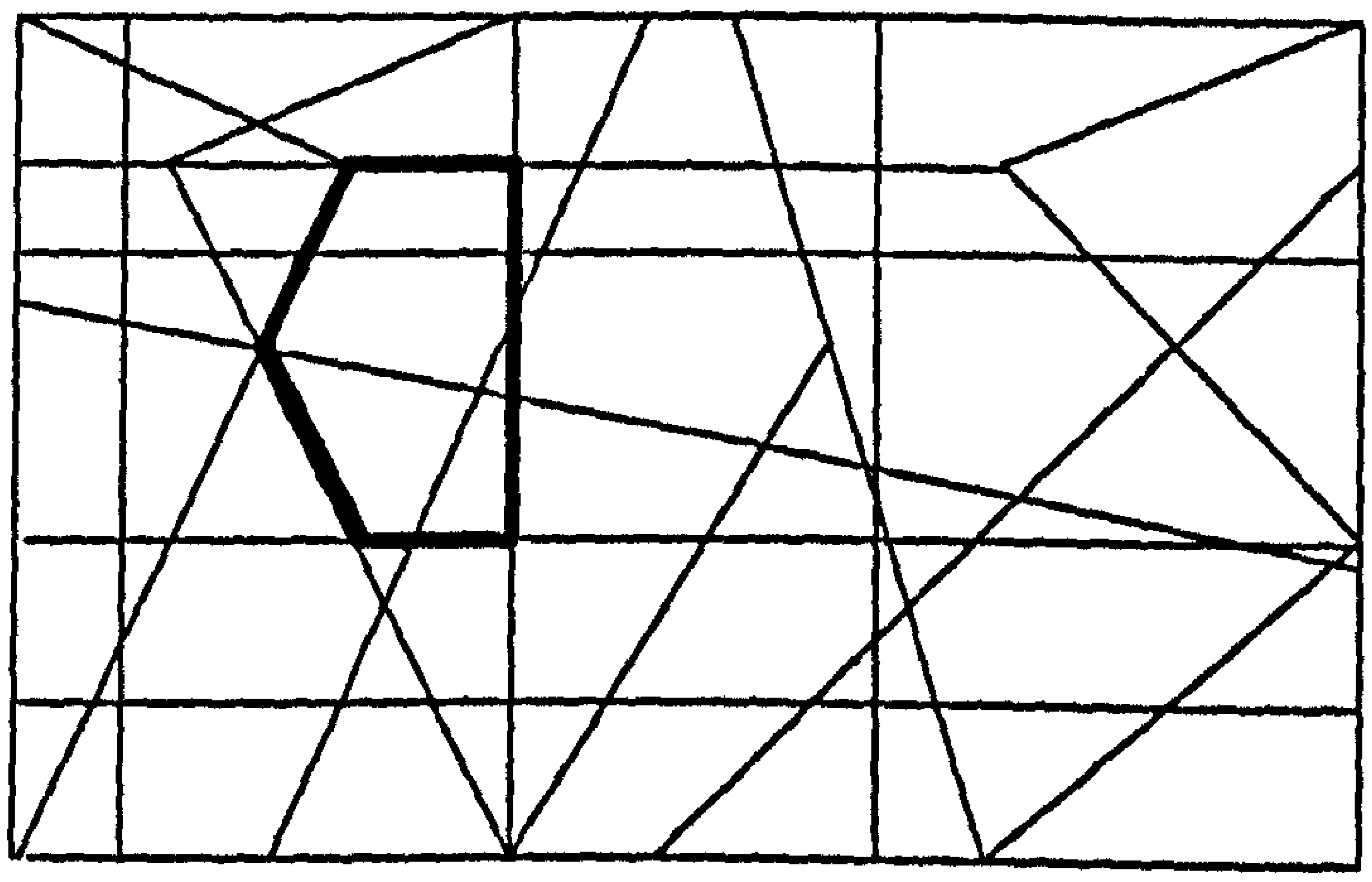
Find SHAPE B



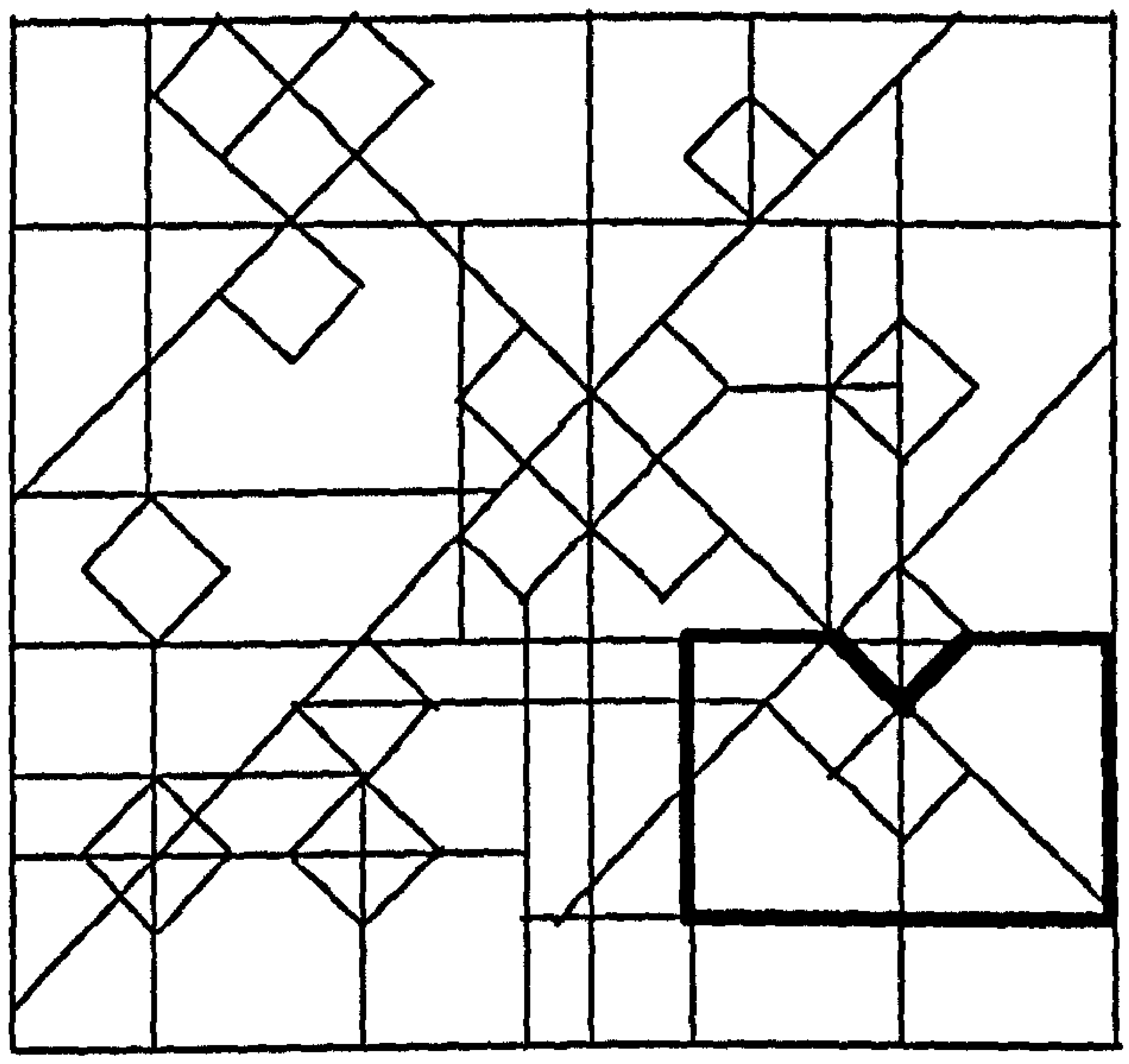
Find SHAPE D



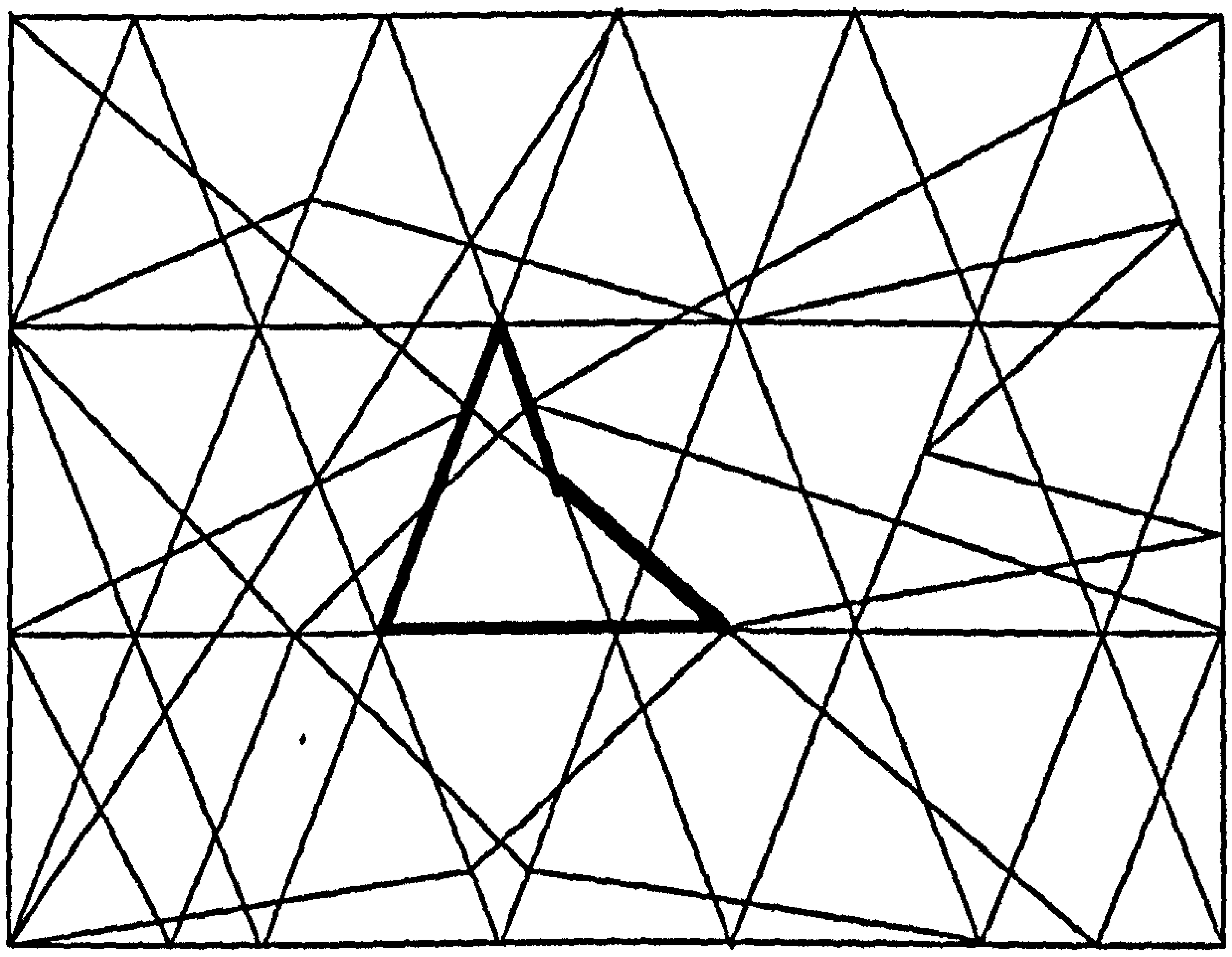
Find SHAPE H



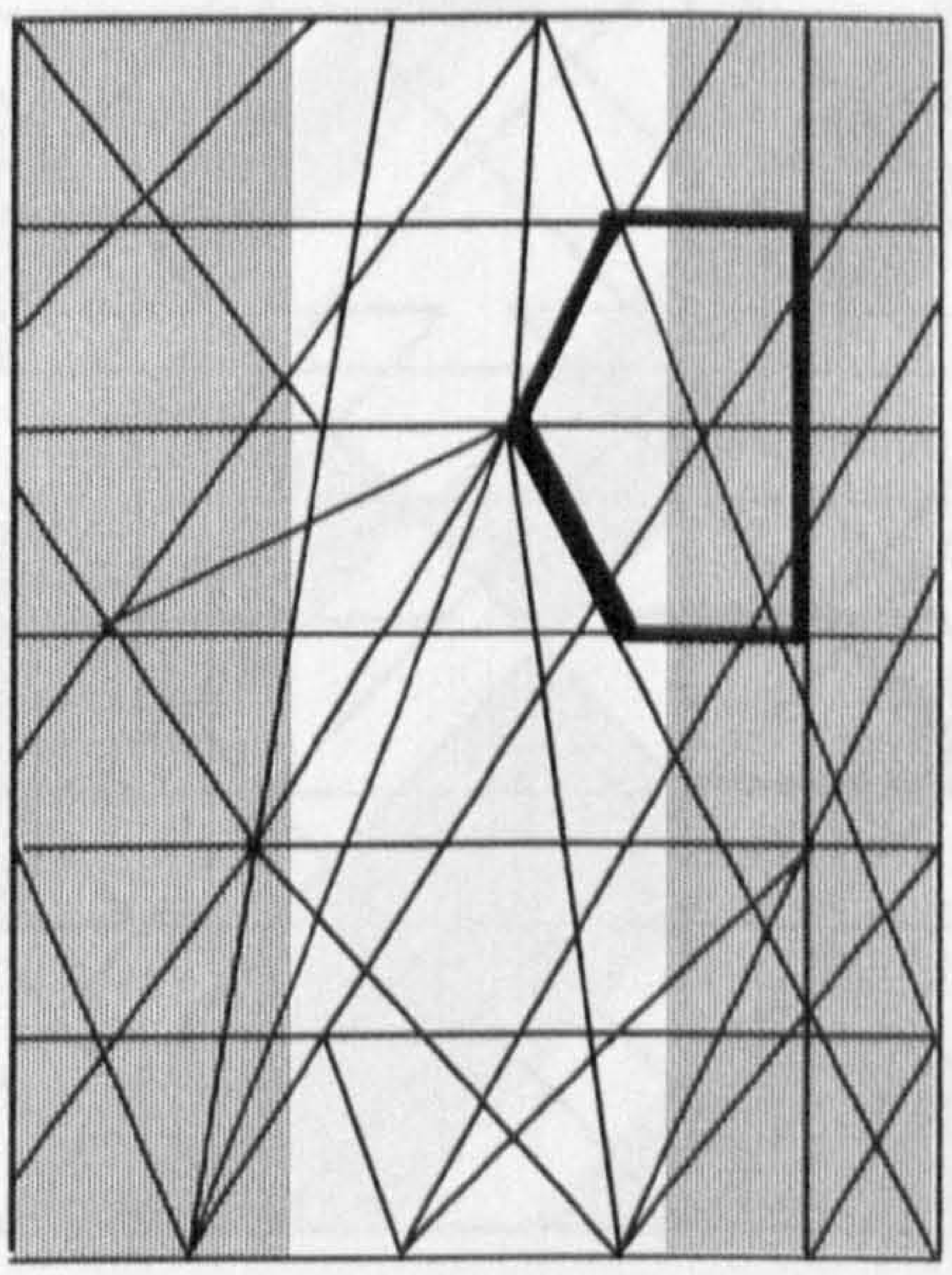
Find SHAPE E



Find SHAPE F



Find SHAPE A



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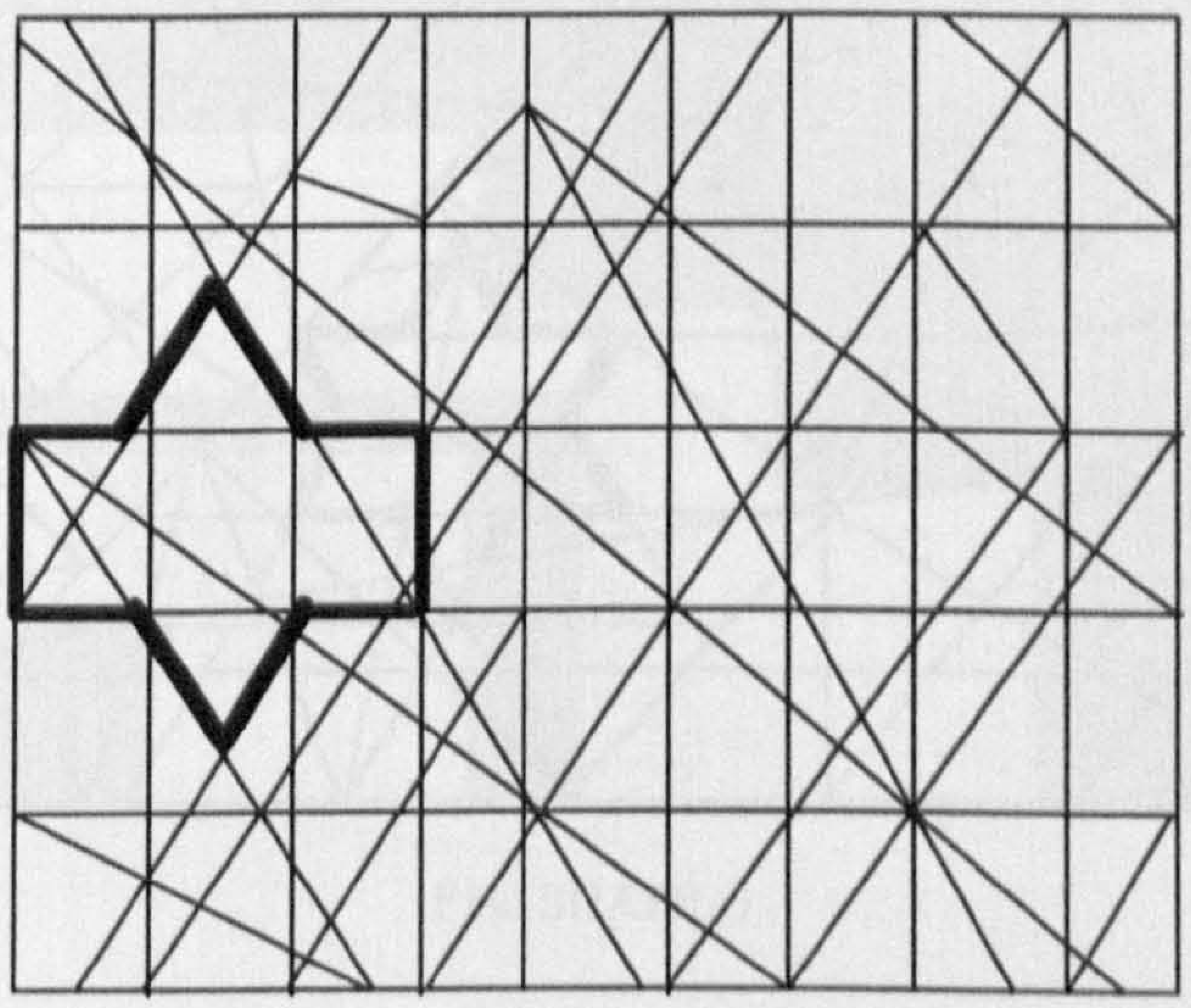

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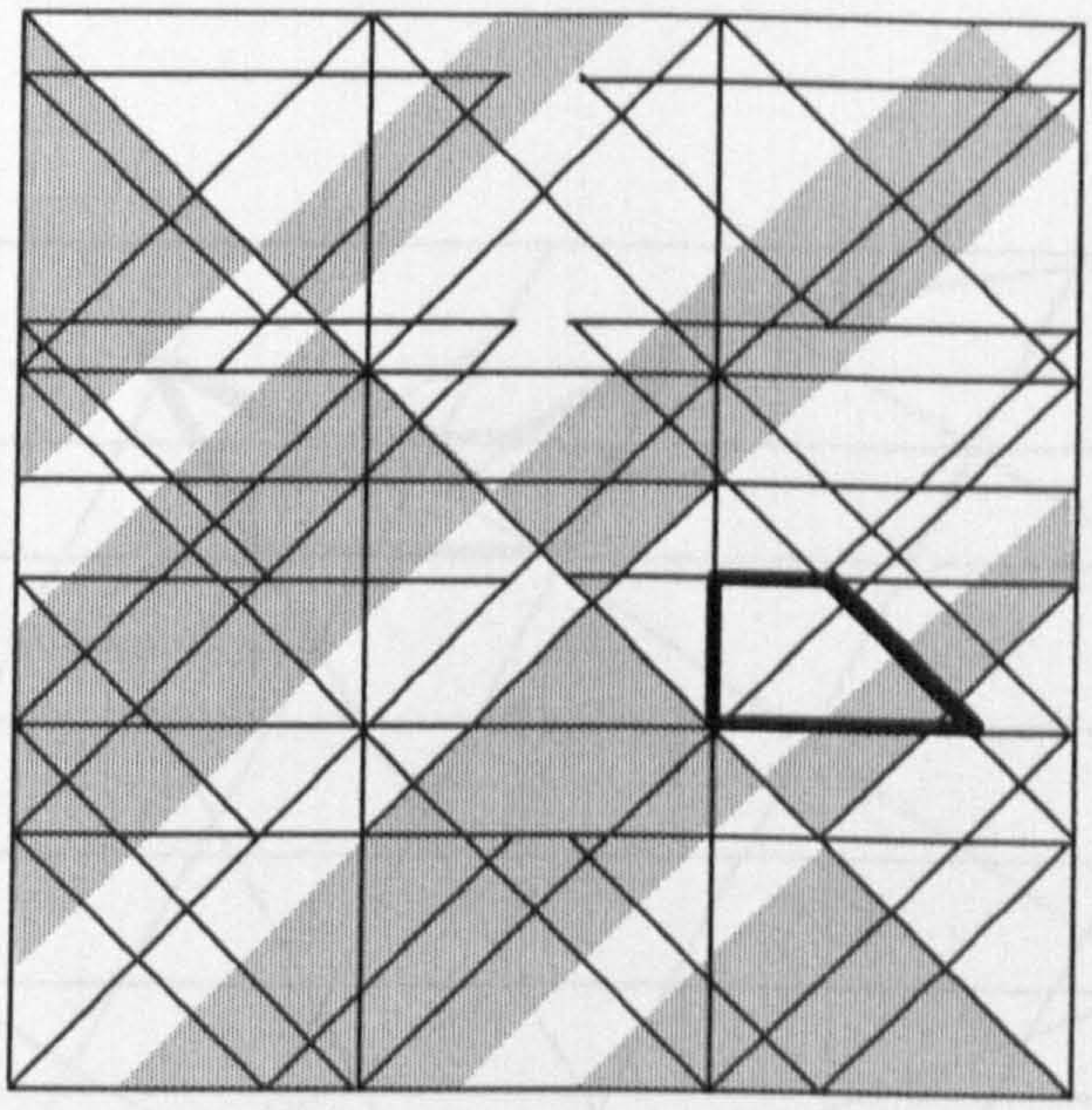

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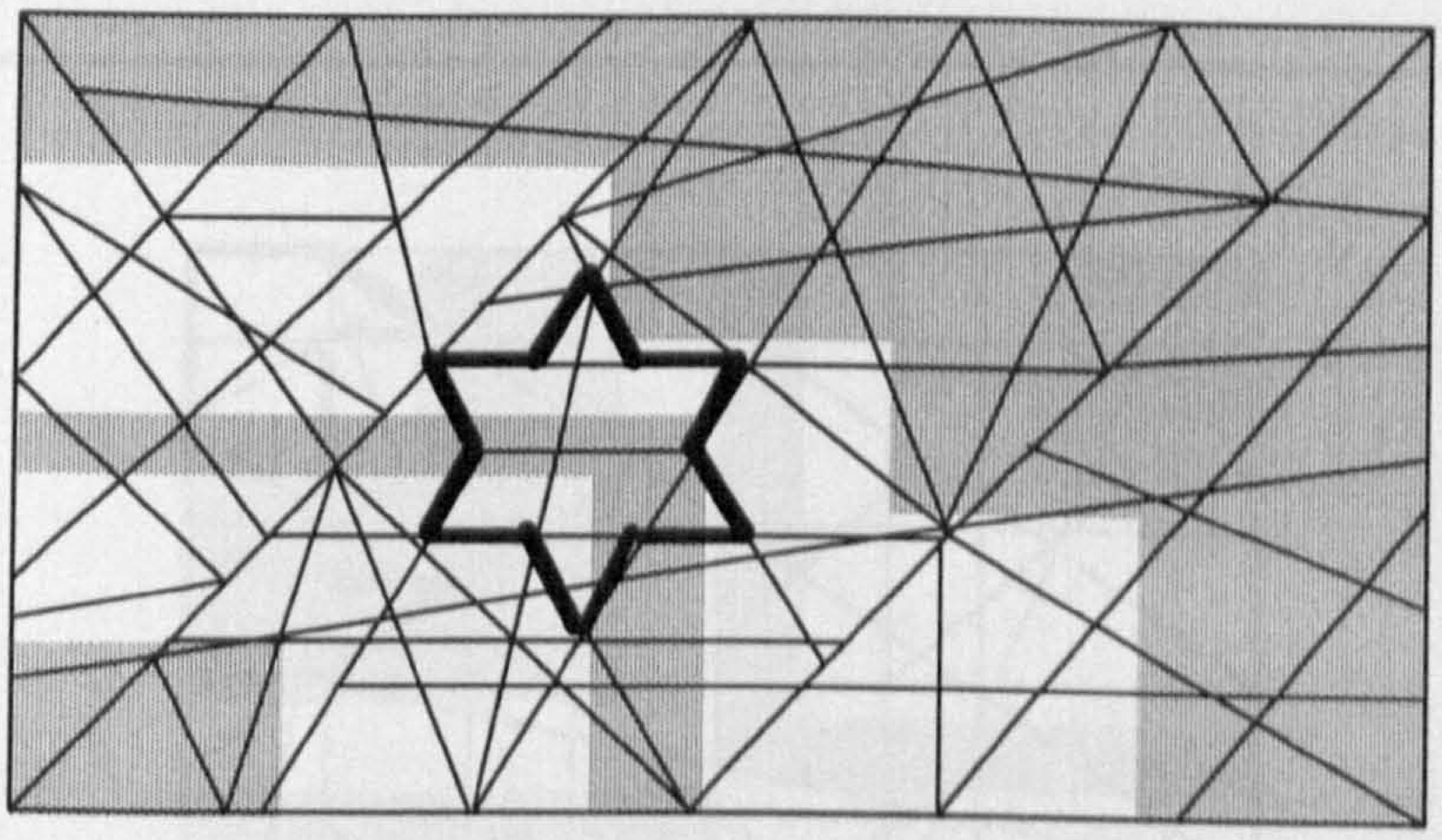

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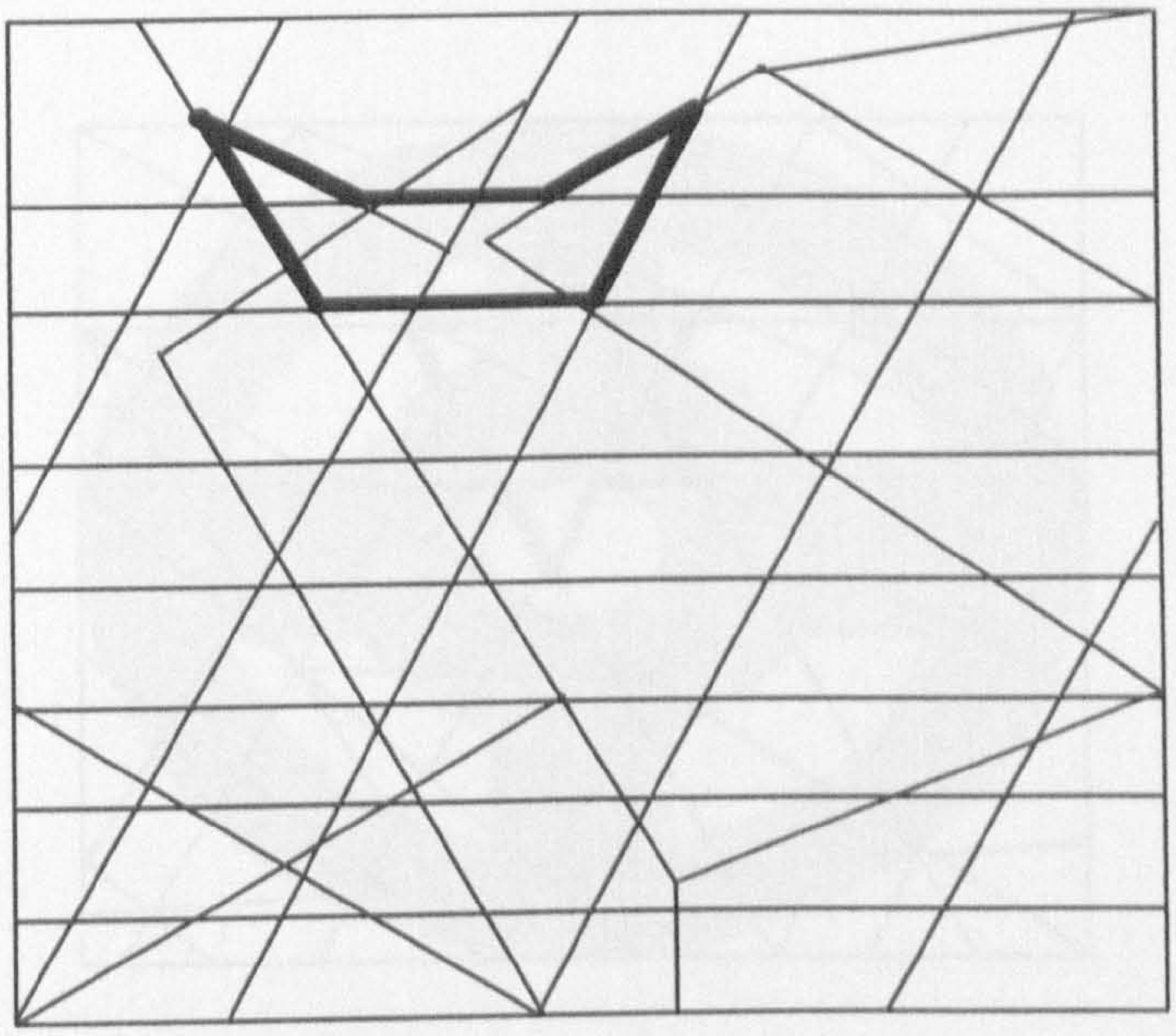

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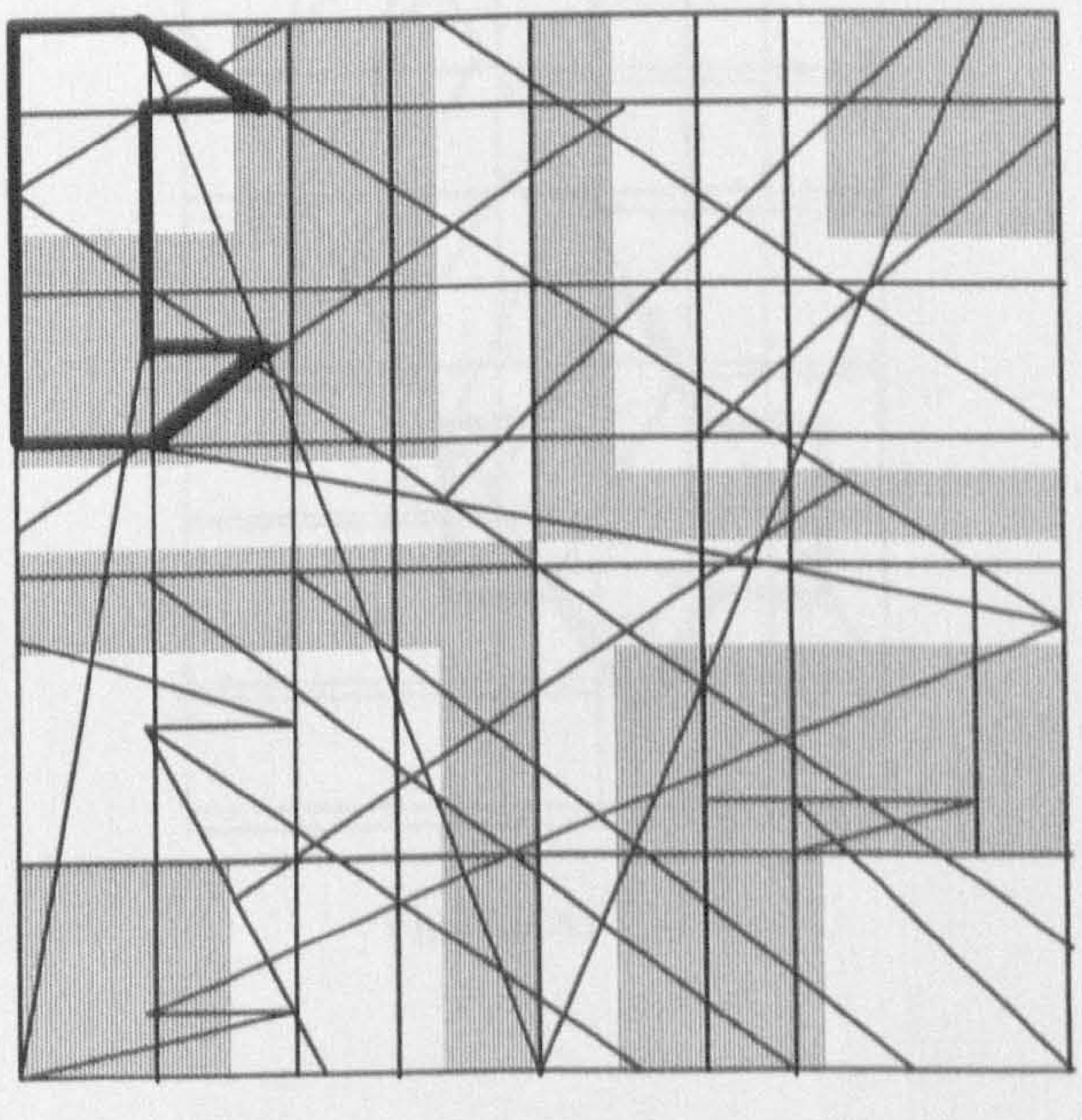

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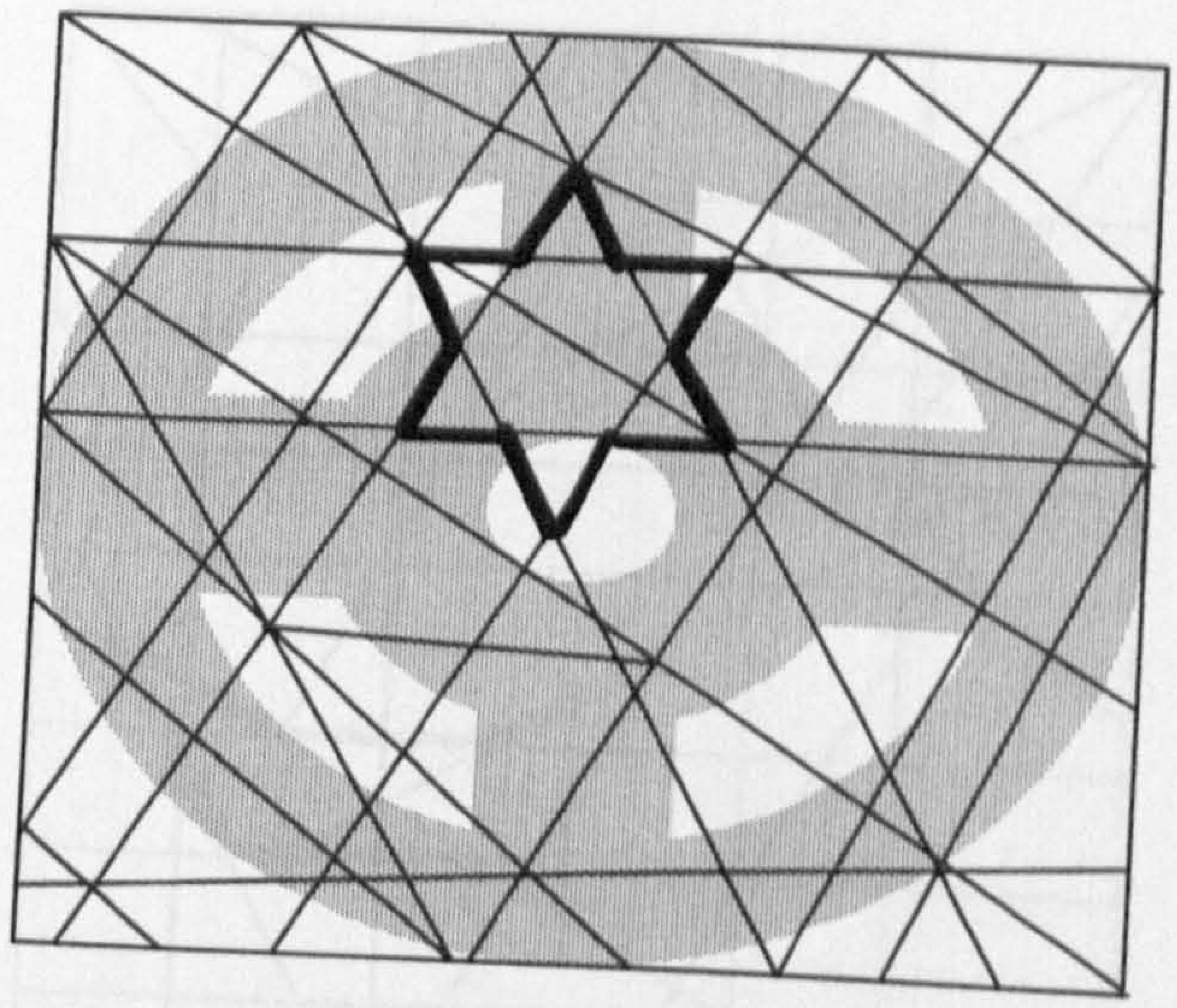

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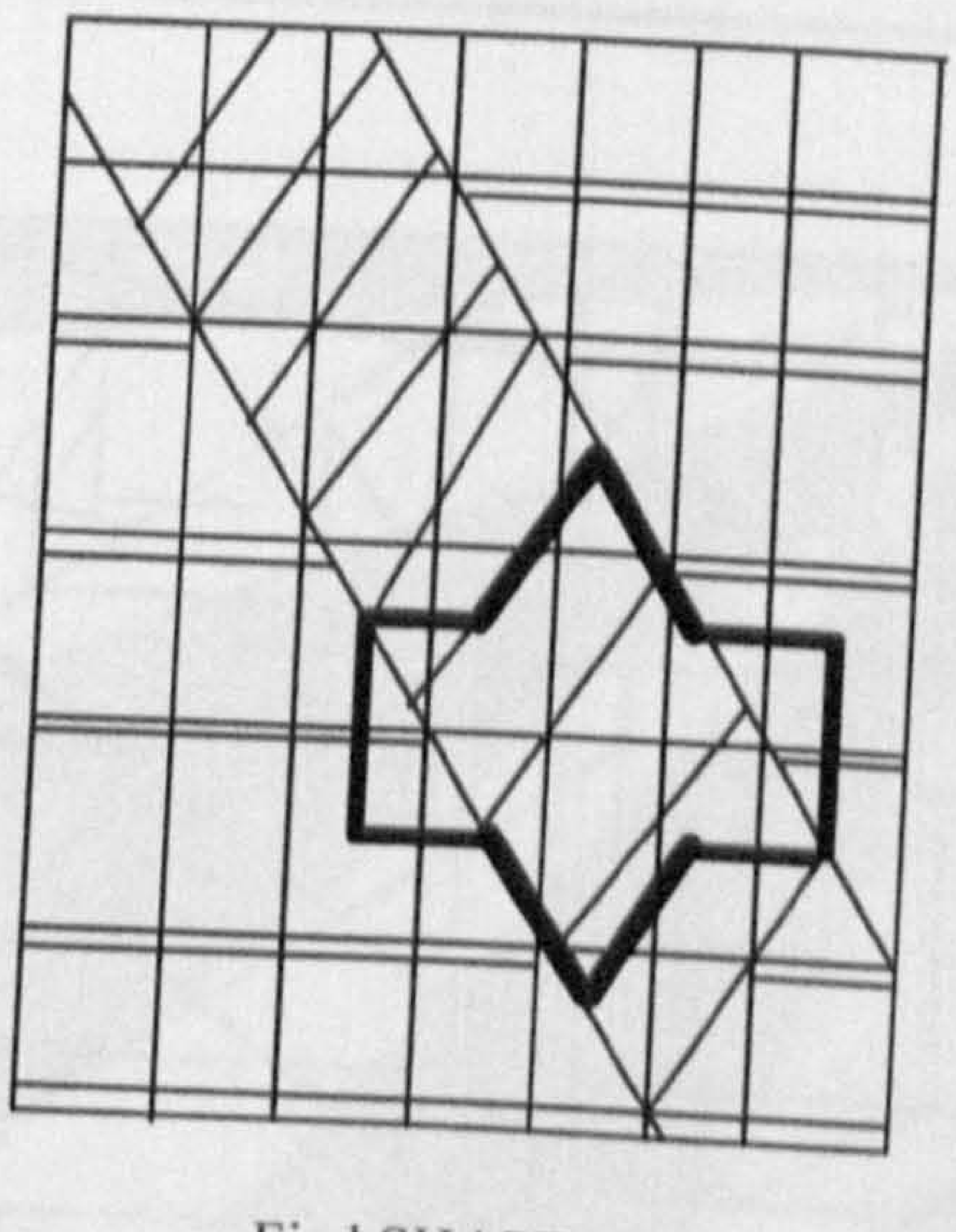

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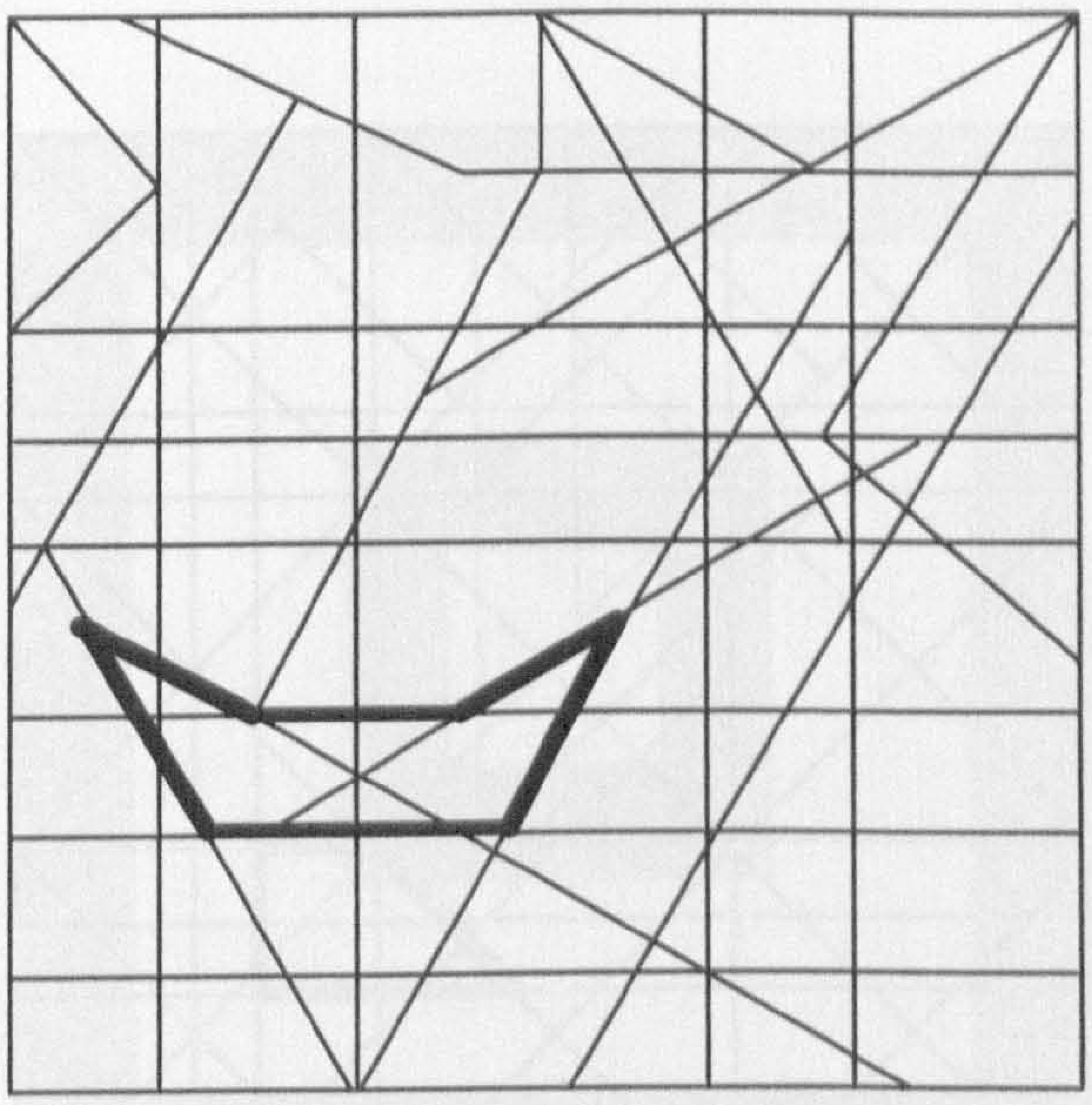

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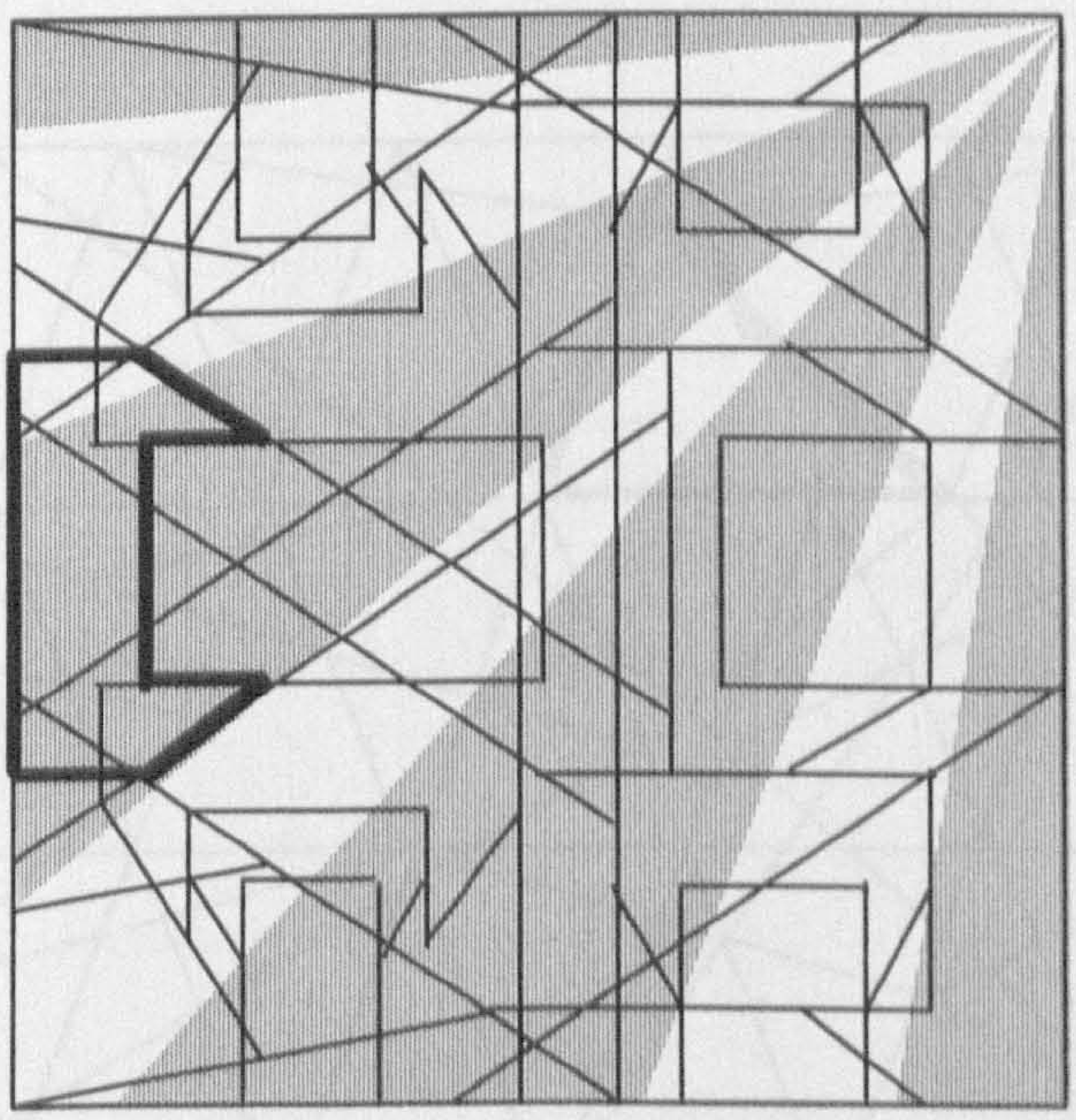

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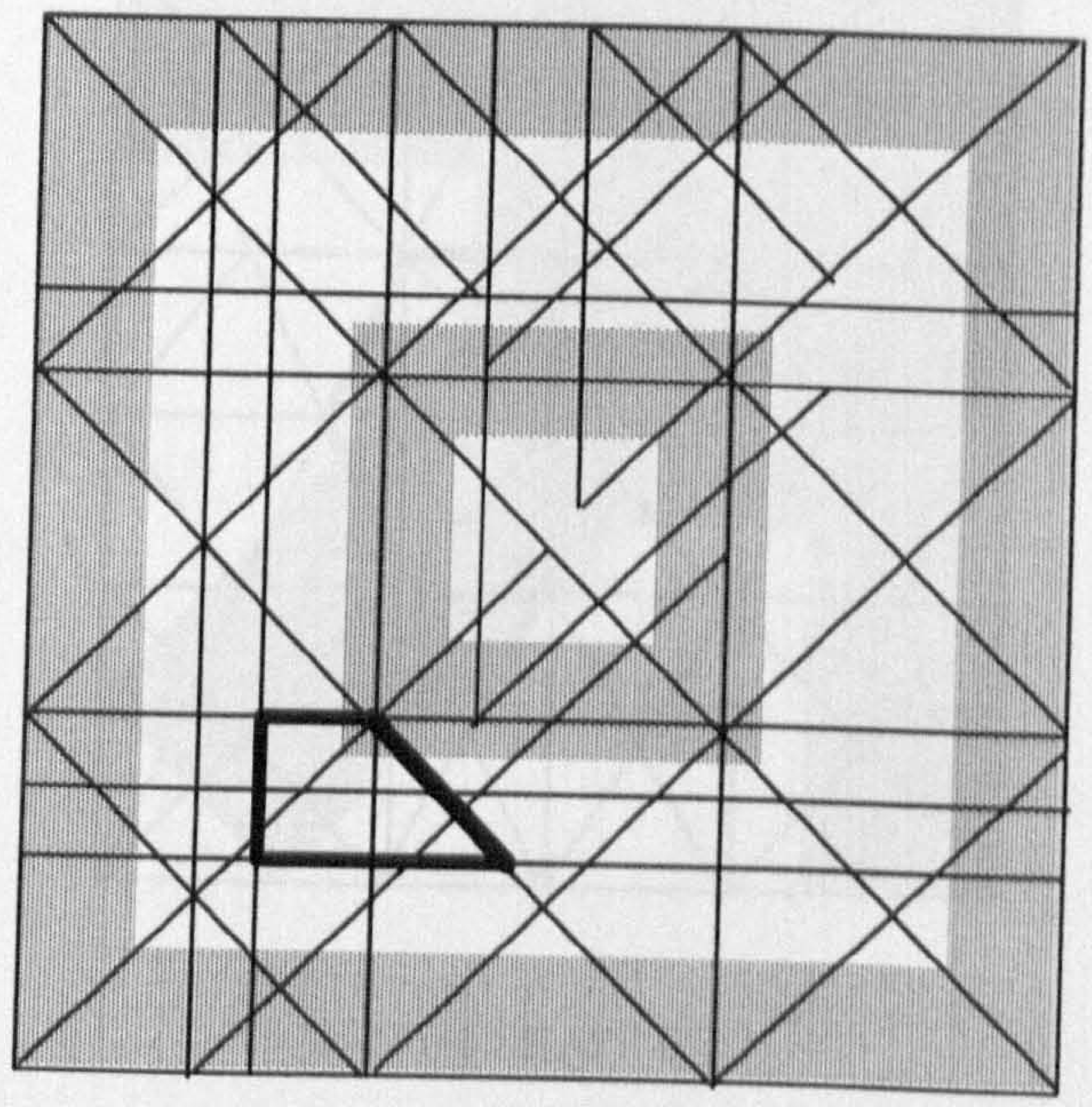

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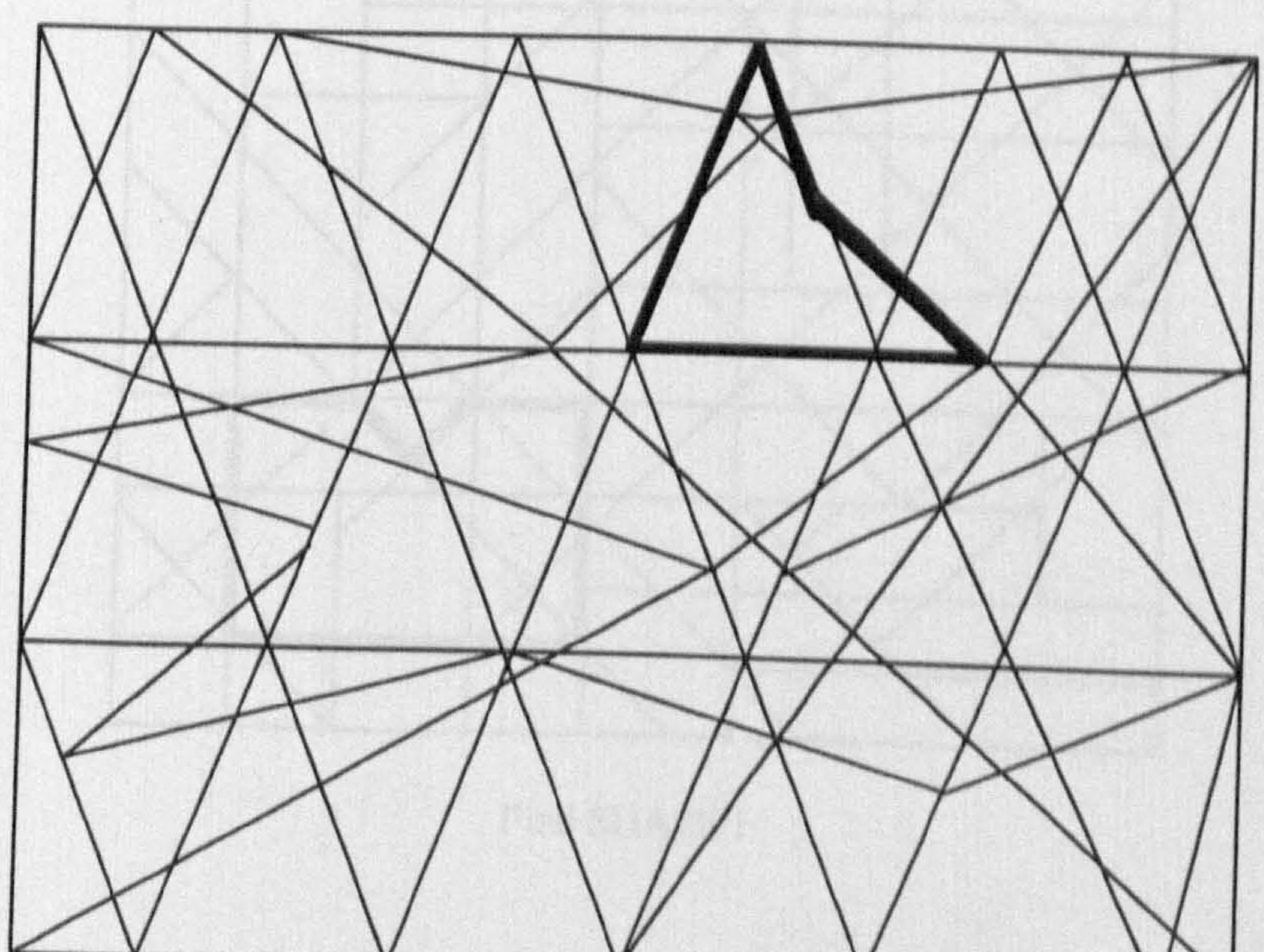

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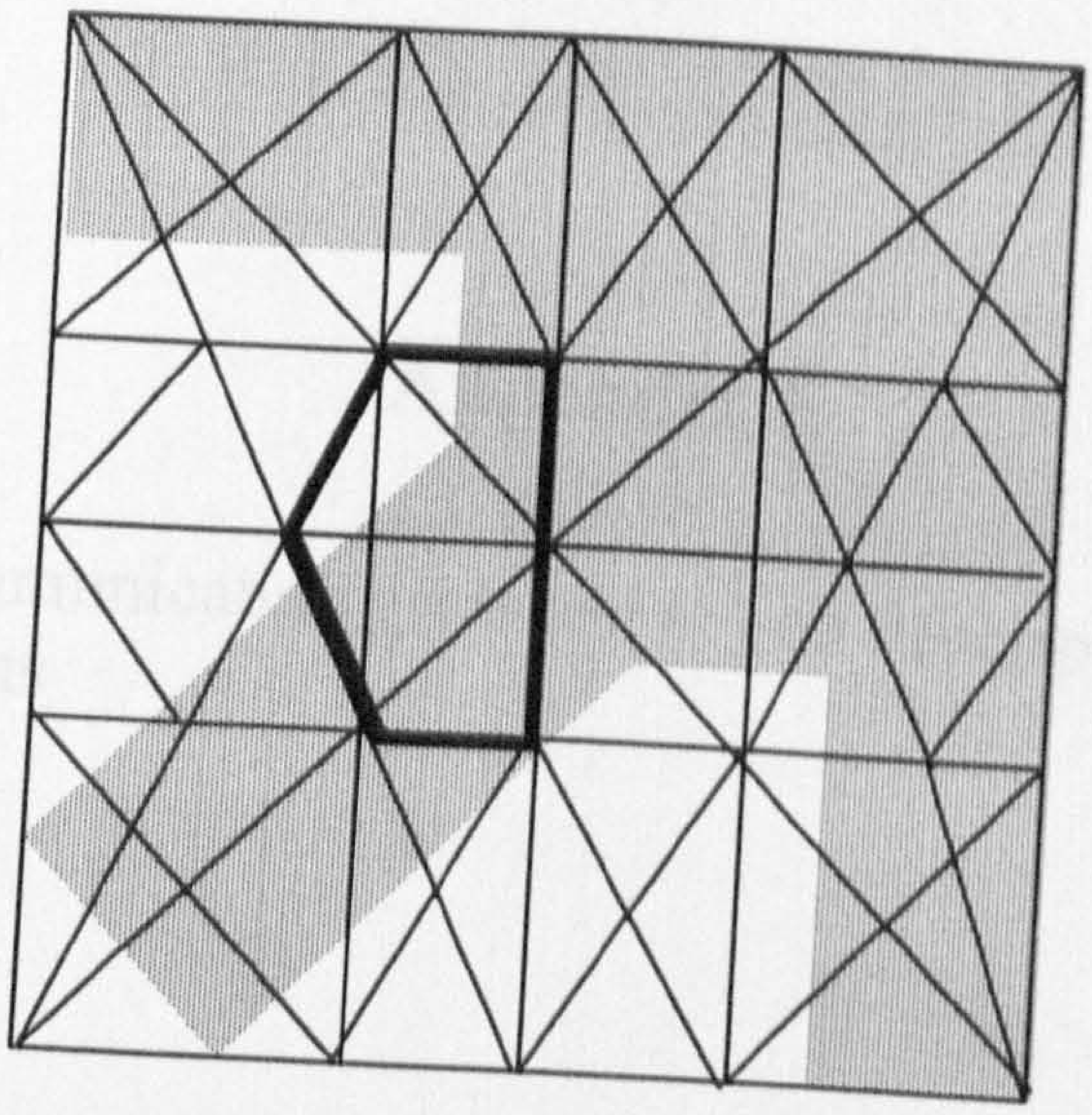

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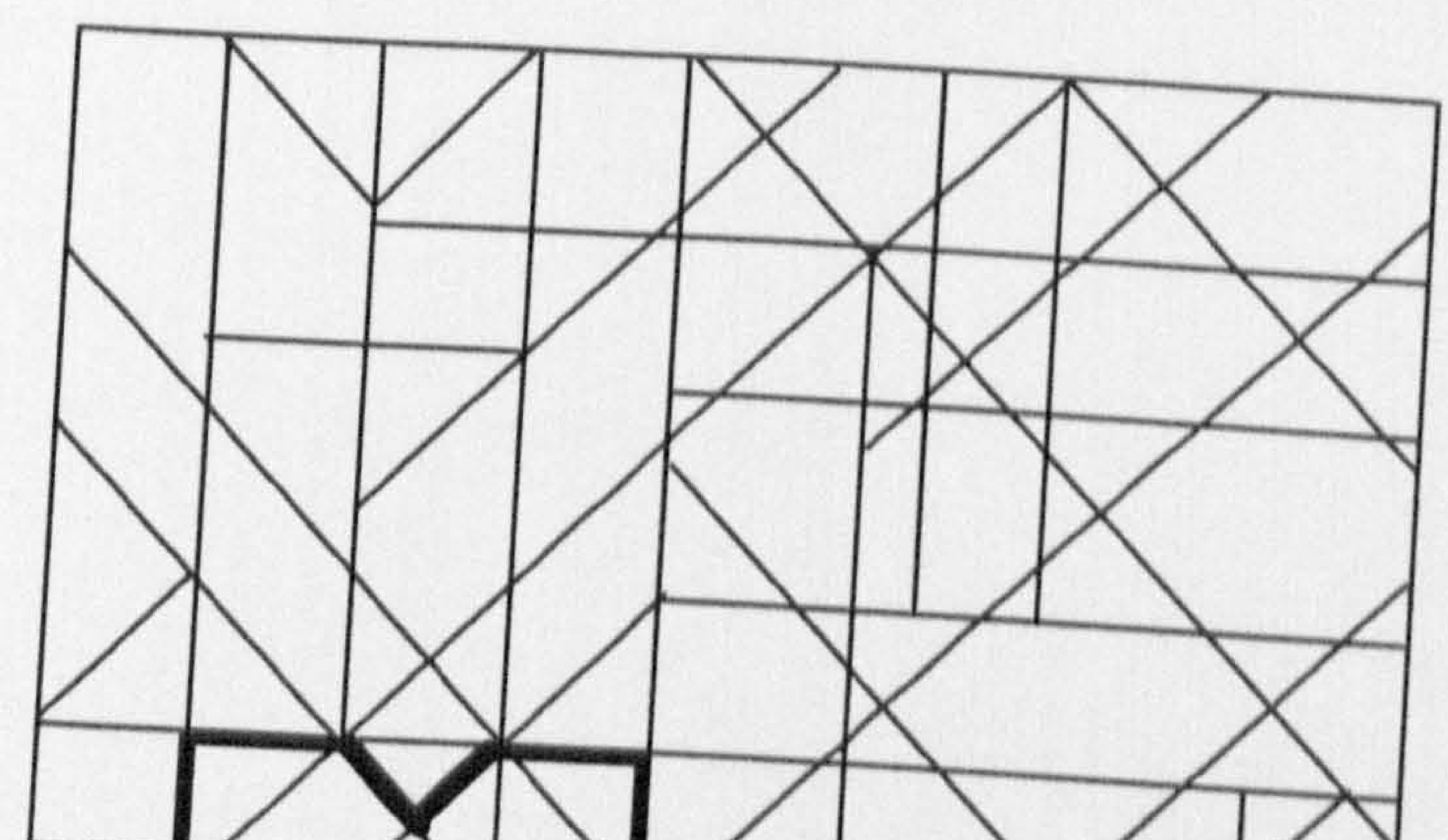


Find SHAPE F

Appendix E

The structural communication grids test (1) on descriptive statistics and probability concepts

Structural Communication Grid (SCG) Test

GRID A

Use the boxes to answer the following questions. Each box may be used more than once. Use the numbers 1,2,...,9 to represent the boxes

1 standard deviation	2 median	3 range
4 mean	5 first quartile	6 variance
7 third quartile	8 mode	9 inter quartile range

A1. Which boxes contain the measures of location?

____

A2. Which box represents the quantity that measures the difference between the largest value and the smallest value?

____

A3. Apart from the smallest value and the largest value from a set of data, which boxes are needed to construct a box plot?

____

A4. To calculate quantity Y, one has only to find the positive square root of quantity X if it is known. Which boxes represent X and Y respectively ?

____

GRID B

A group of students from UPSI wish to have a picnic by the riverside. Let X represents 'the weather would be fine'; Y represents the event that 'food brought would be sufficient' and Z represents the event that 'the picnic would be fun'.

The grid below consists of various events that are associated with the above events.

1 X'	2 Y'	3 Z'
4 $X \cap Y$	5 $X \cap Z$	6 $Z \cap Y$
7 $X \cap Z \cap Y'$	8 $X \cap Y \cup Z$	9 $X' \cup Z \cup Y'$

State the box or boxes which appropriately describe the events below.

B1. The weather is nice and the picnic is fun but the food is not enough.

____

B2. The food is sufficient and the picnic is fun

____

B3. The weather would be bad

____

GRID C

The grid below contains various values of p (probability) for the occurrence of certain events. Use the numbers from the boxes to answer the following questions.
Each box may be used more than once.

1 $p = 0$	**2** $p = 1$	**3** $p > 1$
4 $0 \leq p \leq 1$	**5** $p < 0$	**6** $p = ½$
7 $½ < p \leq 1$	**8** $0 < p < ½$	**9** $-1 < p < 1$

Q1. Which boxes contain impossible values for p?

____

Q2. Which box denotes that an event is certain to happen?

____

Q3. Which box denotes that an event is definitely not going to happen?

____

Q4. Suppose there are 30 students in a class comprising 15 girls and 15 Boys. A teacher wants to choose a student at random from that class. Which box represents the exact probability that a girl is chosen?

____

Q5. Now the teacher decides to choose two students at random. Which boxes represent the likely probability that two boys are chosen?

____

Appendix F

Learning unit 1 – 'Does colour matter?'

Does colour matter?

Part 1

An experimenter wishes to know whether colour of the bead plays a prominent role in determining the results of this simple experiment he performs. He uses a ***sampling bottle*** containing four similar beads of different colours; red, blue, white ,yellow. A sampling bottle is a useful piece of l apparatus which consists of a bottle and a glass tubing. He shakes the bottle well, turns it upside down and notes the colour of the bead at the bottom of the tube. He then records the result and repeat the experiment for 10, 20, 30, 50, 100 and 1000 trials as in the following table.

	Number of trials					
	10	**20**	**30**	**50**	**100**	**1000**
Number of times red	1	5	8	12	24	245
Number of times blue	2	3	5	10	23	253
Number of times white	2	4	6	13	26	248
Number of times yellow	5	8	11	15	27	254

To answer the following questions, please work in pairs.

a) Discuss whether you can draw any conclusion from the rows of frequencies for each colour.

....

....

b) Do you think the experiment above favour any colour?

....

c) Can you predict the frequencies for each colour if the experimenter increases the number of trials to 10 000 ?

....

Part 2

Now you and your partner can do this simple experiment. Toss a coin in the air. Will it land heads or tails? Record the result and repeat the experiment for 100 tosses recording the number of heads and tails after 10, 20, 30, 50 and 100 tosses.

	Number of trials				
	10	**20**	**30**	**50**	**100**
Number of heads					
Number of tails					

d) Express each frequency as a fraction of the number of tosses (to 2 decimal places). To what value does it seem to be tending?

heads :............ tails :..................

e) Can you predict the frequencies for 'heads' and 'tails' if you toss the coin 10 000 times?

....
....

Part 3

The fraction of the coin tosses which come down as 'heads' is known as the ***relative frequency*** of obtaining a 'head'. You may have noticed that the relative frequency of obtaining a 'head' tends to settle down around a half and wil tend to become closer to a half the more tosses are made.

We tend to use the word ***probability***. The probability of obtaining a 'head' is found by dividing the number of 'heads' obtained by the number of tosses made, if a very, very large number of tosses are made

Still working as a pair, try to answer the following questions :

f) What is the probability of obtaining each colour in the first experiment?

P(red) = ... P(blue) = ... P(white) = ... P(yellow) = ...

g) What is the value of P(red) + P(blue) + P(white) + P(yellow) ?

Look at the coin tossing experiment.

h) What is the value of P(heads) + P(tails) ?
....

Thinking generally,

i) What is the highest value which a probability (P) can have?
....

j) What is the lowest value which a probability (P) can have ?
....

Appendix G

Learning unit 2 – 'Who is likely to win'

Probabilities and odds: Who is likely to win

Part 1

The idea of probability was born in a gambling hall in France more than three centuries ago when famous
French mathematicians , Pascal and Fermat helped out a friend who was in deep financial trouble to figure out the best chance in winning a huge sum of money in a gambling game.

Today, betting companies and bookies worldwide make full use of the ideas of probability but they quote probability in terms of ODDS. For example, if an event is twice as likely **NOT** to occur than to occur, we say that the odds are 2 to 1 against that it will occur.

Here is a gambler's column from a newspaper of November 10th 2002

West Ham v Leeds	*Odds Against*
West Ham to win	11-8
Leeds to win	13-8
Draw	12-5

Sunderland v Hotspurs	*Odds Against*
Sunderland to win	9-5
T.Hotspurs to win	13-10
Draw	9-4

Man.City v Man.Utd	*Odds Against*
Man City to win	5-2
Man.Utd to win	10-11
Draw	9-4

Working with your partner,

a) Discuss which is the likely outcome for each match based on the odds given. State the reason for your choice.

West Ham v Leeds : ....

....

Sunderland v Hotspurs :..

....

Man. City v Man. United : ....

b) In betting, the word odds is used to denote the ratio of the wager of one party (the bookie) to that of another (the punter). For example, as a Man. City fan, John puts a bet of $10 for his team to win and the odds quoted against a City victory are 5 to 2 . If Man. City does win, he would make a profit of $25 because for every $2 he bets, he would gain $5 . Another punter bets that the match would end up in a draw and he puts down $12 as the wager with the odds at 9 to 4 against. How much money would he gain if the match does indeed end up in a draw.

....

c) A neutral fan wishes to spread his bets for the Man. City v Man. Utd game. He puts down $4 as a wager for Man. City to win, $11 for Man.Utd to win and $12 for the match to be drawn. If the actual outcome of the match is a draw, how much profit does he make?

....

Part 2

We need to know how to translate odds into probabilities. Odds of **A to B** against an outcome means that the probability of that outcome is **B / (A + B)**. For example, in the match West Ham v Leeds, the probability of West Ham winning is 8/19, the probability of Leeds winning is 8/21 and the probability of a drawn match is 5/17

d) Calculate the probabilities for the outcomes in Sunderland v T.Hotspurs match

P(Sunderland to win) = ...

P(Hotspurs to win) = ...

P(draw) = ...

What is the most likely outcome for the match? ....

What is the value of P(Sunderland to win) + P(Hotspurs to win) + P(draw)
....

e) Calculate the probabilities for the outcomes in Man. City v Man. Utd match.

P(Man.City to win) = ...

P(Man.Utd to win) = ...

P(draw) = ...

What is the most likely outcome of the match? ....

What is the value of P(Man.City to win) + P(Man.Utd to win) + P(draw) ?
....

Appendix H

Learning unit 3 – 'The three doors'

Simulating probabilities : *The three doors*

In a game show , the final contestant is shown three doors where the prizes are kept. Behind one door is a car. Behind each of the other two doors is a goat. The final contestant is asked to select a door with the idea that you will receive the prize that is behind that door. The game show's host knows what is behind each door.
After you select a door, the host opens one of the remaining doors that has a goat behind it. Note that no matter which door you select, at least one of the remaining doors has a goat behind it for the host to open. The host then gives you the following two options :

1) **Stay with the door you originally selected and received the prize behind it.**
2) **Switch to the other remaining closed door and receive the prize behind it.**

Part 1

Working in pairs, try to answer the following questions:

a) What is the probability of winning the car if the contestant stays with the original door?

....

b) What is the probability of winning the car if the contestant switches to another door?

....

c) Will switching increase the contestant's chance of winning the car? Why?

....
....
....

Part 2

If the answer is not clear, you could carry out the following activity:

1. You will use a set of three cards (a black-suited card and two red-suited cards) which your tutor will give you.
2. You can be the games show host and your partner can be the final contestant.
3. The host controls the three doors represented by three cards. The black-suited card will represent the car and the two red-suited cards will represent the goats.
4. The host will lay out the three cards blank side up having the knowledge which card has the car on the other side.
5. The contestant begins playing the game with the strategy being to **STAY** with the original choice of door. Record the outcome as either win a car or win a goat in the table below with a tick (/).

Play the game 20 times, on each occasion the contestant should **STAY** with the original choice of door. Record the outcomes on the table below.

6. Now change over and play the game another 20 times. This time, the contestant should **SWITCH** from the original choice. Again, record the outcomes as either win a car or win agoat on the table below

Strategy - **STAY**			Strategy - **SWITCH**	
Win Car	Win Goat	/	Win Car	Win Goat

Summarize the results as follow:

1. Of the 20 repetitions for which you **STAY** with the original door, what proportion of times did you win the car?

....

2. Of the 20 repetitions for which you **SWITCH** to the remaining door, what proportion of times did you win the car?

....

3. What is your estimate of the probability of winning when you **STAY**?

....

4. What is your estimate of the probability of winning when you **SWITCH** doors?

....

5. Which strategy has the better chance of winning the car?

....

Appendix I

Learning unit 5 – 'Who are the best students?'

Who are the best students?

Part 1

A class of 34 students sit for examinations in six subjects. The scores for each subject are given as percentages. The class teacher wishes to award the top three students with prizes . All the scores are presented in the following table and the names are listed alphabetically.

No	Name	Malay	Eng	Mat	Sci	Geo	Hist
1	Abdul Halim Ali	74	71	62	49	58	67
2	Ahmad Kamal Hamid	61	54	63	28	74	62
3	Alvin Harry	61	56	61	64	55	60
4	Aniza Yusuf	56	69	68	66	62	56
5	Anuradha S.	63	50	67	75	74	61
6	Ang Siew Wei	62	71	79	79	56	60
7	Azman Rejab	64	63	55	69	44	62
8	Azmilawati Omar	62	65	70	60	65	69
9	Bahauddin Iman	79	74	45	76	86	77
10	Bahazila Razali	77	62	72	78	73	74
11	Balasundram M	58	46	45	71	66	78
12	Chan Ban Tian	66	78	86	76	75	65
13	Chandler Soong	57	77	82	65	51	49
14	Cumaraswamy K.	66	74	59	74	56	71
15	Dana Taha	69	69	50	72	66	65
16	Daslina Amran	75	50	40	84	73	74
17	David Lee	58	67	56	74	73	66
18	Emma Majid	76	52	74	66	32	65
19	Farah Idris	79	55	73	57	71	66
20	Farid Ikhwan	71	48	52	71	74	66
21	Fauzi Ghazali	74	63	52	70	47	51
22	Fazidah Wahid	66	58	60	70	72	81
23	Fern Tee Mui	61	60	52	75	75	79
24	Hasnida Zaki	79	67	67	82	62	72
25	Hashim Mohamad	73	64	51	68	66	58
26	Herminder Kaur S.	75	33	65	75	62	67
27	Imran Jawi	66	81	55	76	70	71
28	Juliana Sudin	70	56	62	69	51	74
29	Kamaludin Annuar	66	77	52	67	59	66
30	Khairul Anuar Bidin	76	56	60	81	68	62
31	Loo Kum Hui	67	74	57	67	50	77
32	Mariana Idris	71	42	55	64	71	73
33	Mohd Radzi Idris	57	53	58	55	71	78
34	Mohd Saiful Ali	73	51	38	42	49	65

Working in pairs

a) Discuss your approach in selecting the 3 best students

....
....

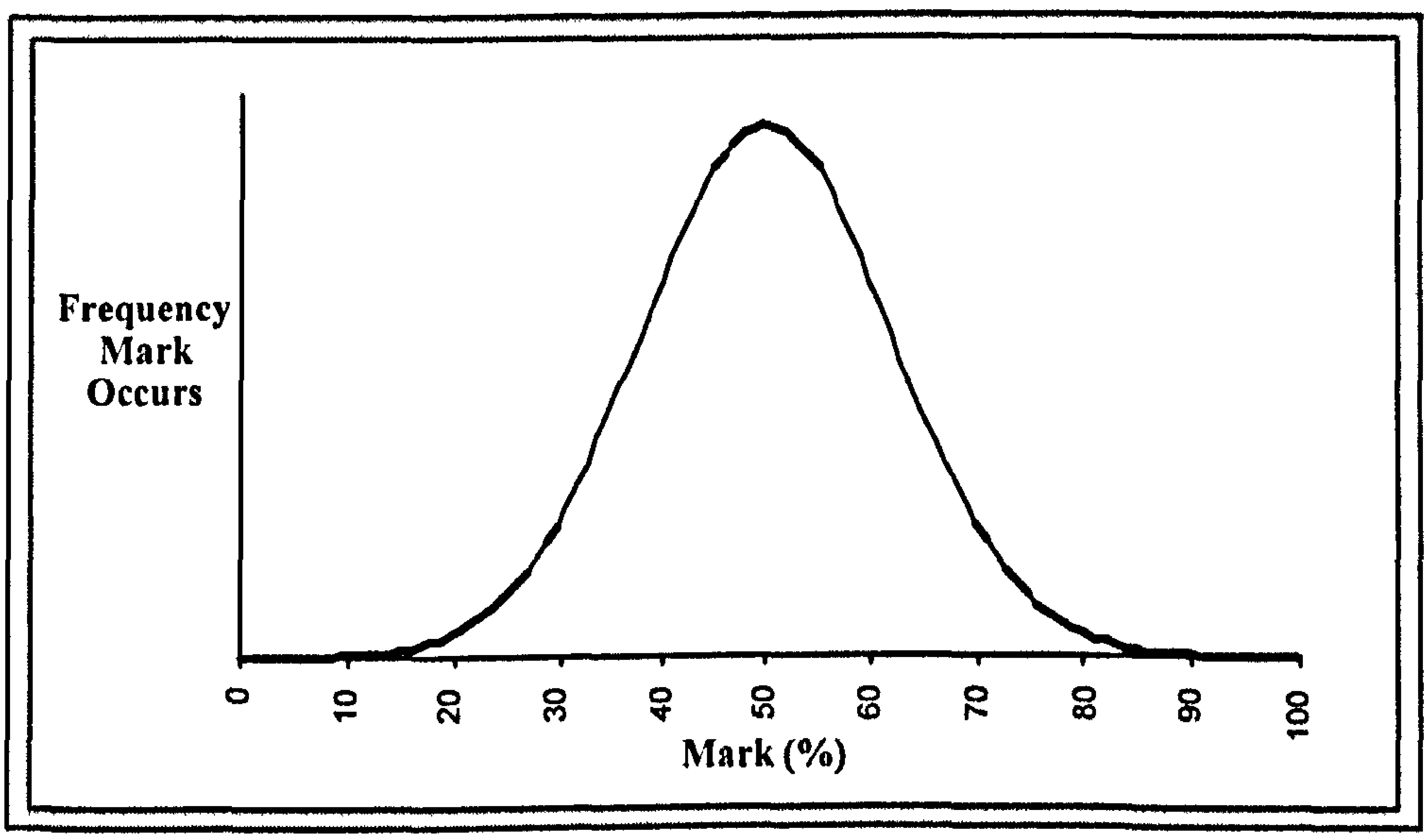
b) It is calculated that the mean mark for Mathematics is 60.1 whereas the highest mark is 86 and the lowest is 38.For Science ,the mean mark is 68.1 and the highest and lowest marks are 84 and 28 respectively. Juliana Sudin obtains 62% for Mathematics and 69% for Science. In which subject does she perform better? Why?

....
....
....

Part 2

Exam or test scores like 68% and 86% are meaningless unless we know the average score and the way the scores are spread out. For example , a score of 68% might be brilliant if the average was 46% and most of the scores fell between 30 % and 62%. On the other hand, a score of 86% might not be so good if the average was 80%.

Scores tend to spread out as in the diagram below :



To compare acores, we have to allow for the average and the way the marks are spread out.
The average is known as the ***mean*** and is easy to calculate.
The scores spread is shown by a number called the ***standard deviation*** . It is much more difficult to calculate but a computer makes it easy.
In the diagram above, the mean is 50% and the standard deviation happens to be 12.
Using the mean and standard deviation, we can convert all the scores into a kind of standardized scores. We can thencompare subjects with each other correctly. It gives what is known as a ***z-score*** which can be obtained by subtracting its mean from the exam score and then dividing by its standard deviation.

As an example, given that the mean score and standard deviation for Science is 68.1 and 11.5 respectively and the mean score and standard deviation for Geography is 63.4 and 11.4 respectively, Fern Tee Mui's z-scores for Science (75) and Geography (75) are calculated as follows:

Science : $z = \frac{75 - 68.1}{11.5} = 0.60$

Geography : $z = \frac{75 - 63.4}{11.4} = 1.02$

Based on the z-scores, it is obvious that Fern's achievement is better in Geography than in Science. A z-score of 0.60 means that the test score is located 0.60 times standard deviation above the mean score. If z has a negative value (say –1), it means that a test score is-1 times the standard deviation below the mean score.

z-scores are pretty meaningless if we present them to pupils or parents.
The best way is to take the z-score and convert it back to a percentage on a scale where the mean is 50 for all subjects and the standard deviation is fixed for all subjects. 10 is a convenient standard deviation.

Thus, Fern's Science score becomes : (10 x 0.60) + 50 = 56

Her Geography score becomes : (10 x 1.02) + 50 = 60

These scores can now be compared because we have adjusted them to the same mean and standard deviation.

c) The class teacher decides that Bahauddin Iman , Bahazila Ramli and Chan Ban Tian are the three best students. Your task now is to compare their achievement using the standardized scores and given the following information:

Subject	Mean score	Standard Deviation
Malay Language	67.9	7.1
English Language	61.4	11.5
Mathematics	60.1	11.3
Science	68.1	11.5
Geography	63.4	11.4
History	67.3	7.9

Who performs better overall? Why?

....
....
....

Appendix J

Learning unit 4 – ' Can midterm test scores predict the final exam scores?'

Can midterm test scores predict final exam scores?

A mathematics lecturer at Sultan Idris Education University wishes to find out whether there is a relationship between the midterm and final exam scores for students enrolled in his Introductory Linear Algebra course. He chooses a sample of 26 students which are listed below.

Student Matric. No.	Midterm score	Final exam score
2321	39	62
2340	44	69
2355	32	68
2367	40	86
2376	45	89
2379	46	89
2395	33	76
2403	39	67
2411	33	75
2427	21	38
2436	30	71
2440	39	88
2448	44	97
2464	29	72
2471	38	96
2489	43	83
2495	42	85
2501	26	28
2510	47	95
2522	36	39
2524	32	58
2538	32	49
2544	42	62
2545	21	59
2552	41	90
2569	30	40

a) Working in pairs, discuss what the lecturer should do to find out whether there is a relationship between midterm and final exam scores. Write your agreed opinion here.

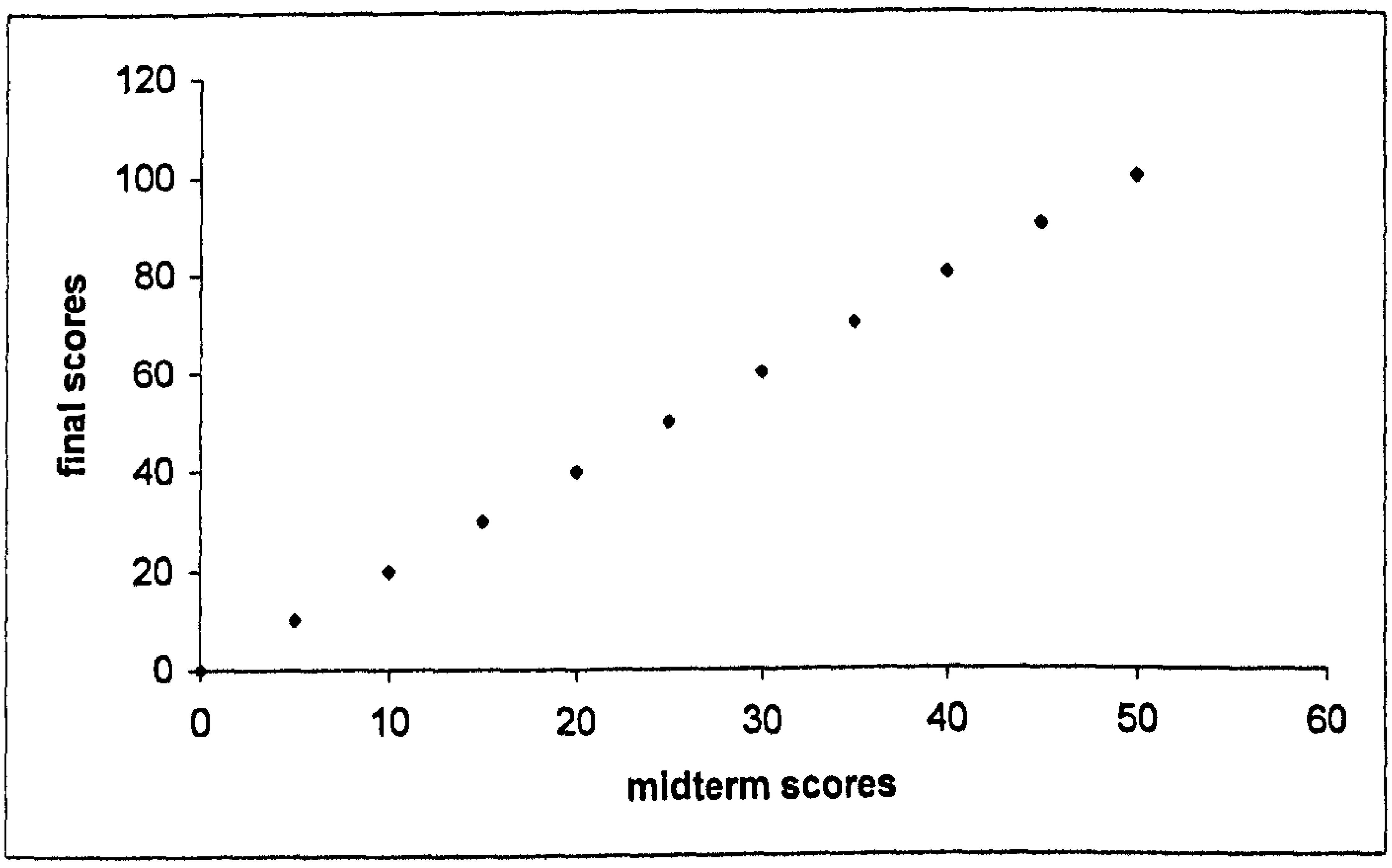
....

....

....

....

b) Still working as a pair, plot the points of Final exam scores vs Midterm scores below. (One person reads the scores while th other plots them).



This is known as a ***scatterplot.*** How might you interpret the scatterplot?

c) We say that the two exam scores are ***positively associated*** when the larger values in one exam tend to go with the larger values in the other. Positive or negative association indicates the direction of the scatterplot. What is the direction in this scatterplot.

....

....

d) If the two sets of exam scores are positively associated, we can comment on the ***strength***. The strength of an association reflects how tightly clustered the points are. How would you describe the strength of this scatterplot?

....

....

e) Is it possible to predict a student's final exam score by looking at his midterm exam score?

....

f) It is possible to measure the strength of the association. This is done by calculating the ***correlation coefficient.*** The correlation coefficient is given the symbol ***r***, and has a value between −1 and +1. If the value is positive, then there is a positive association between the two sets of scores. Here is a table which shows the meaning of some values of ***r***.

Magnitude of correlation coefficient (r)	**Strength of the relationship**
0.0 – 0.2	Very low
0.2 – 0.4	Low
0.4 – 0.6	Moderate
0.6 – 0.8	High
0.8 – 1.0	Very high

Predict a very approximate value of ***r*** which you think you might expect from your scatterplot.

....

g) The correlation coefficient is usually calculated using statistical software like SPSS, Excel or Minitab. Now ask your tutor for the value of r for the midterm/final exam data.
How close was your prediction?

....

Here is the formula which is used to calculate ***r***

$$\frac{\sum xy - \frac{\left(\sum x\right)\left(\sum y\right)}{n}}{\sqrt{\left(\sum x2 - \frac{\left(\sum x\right)2}{n}\right)\left(\sum y2 - \frac{\left(\sum y\right)2}{n}\right)}}$$

Appendix K

Pre- questionnaire for the field experiment

Centre for Science Education, University of Glasgow.

This questionnaire is part of a project investigating the teaching and learning of Statistics for student teachers.
All information obtained would be treated confidentially

Please tick (√) the relevant box or fill in the dotted lines

1. Are you : ☐ Male ☐ Female

2. Matric no. : ....

3. Semester of study : ☐1 ☐2 ☐3 ☐4 ☐5 ☐6

4. Programme of study : ☐ Mathematics education ☐ IT education ☐ Science education & others

6. **Your attitudes towards statistics** . Please tick (√) the box that best indicates your views.

	Statement	S.A.	A	N	D	S. D.
1.	I like to study statistics					
2.	Statistics is difficult to learn					
3.	Statistics is a useful tool in everyday life					
4.	I don't like statistics					
5.	Statistics is easier than other branches of Mathematics					
6.	A lot of difficult concepts in Statistics					
7.	Statistics is a challenging subject					
8.	I enjoy the statistics course that I am currently studying					
9.	It would be easier to study statistics using statistical softwares					
10.	I feel as confident about coping with my statistics course as I do about other courses					

Indicator : SA-strongly agree A-agree N-neutral D-disagree SD-strongly disagree

You are provided with pairs of opposing statements with five boxes in between. By ticking ONE of the boxes, you can show which statement you agree with and how strong your agreement is. Here is an example :

Statement						Statement
Life as a university student is stressful						I am more relaxed as a university student

If you tick the first box on the left, it means that you strongly agree with the statement on the left. If you tick the second box, it means you favour the statement on the left side but less strongly. If you tick the third box, it means you are neutral and you don't favour any statement. The other two boxes on the right reflect agreement with the statement on the right side.

7.Your opinions on the Statistics course being taught here. Please tick (√) the box which reflects your view best.

Statement						Statement
Easy						Difficult
Boring lectures						Interesting lectures
Heavy workload						Light workload
Course too mathematical						Course less mathematical
Too many tests and quizzes						Too few tests and quizzes
Real life data are rarely used in examples						Used real life data in examples
Too many tedious calculations involved						Not a lot of calculations involved
No statistical software being used in teaching and learning						Usage of statistical software is common
Little emphasis is given in the interpretations of statistical results						The interpretations of statistical results are greatly emphasised
The lecturer shows very little how Statistics can be used in everyday life						The lecturer shows how Statistics can be used in daily life a lot

Appendix L

Post- questionnaire for the field experiment (experimental group)

Centre for Science Education, University of Glasgow.

This questionnaire is part of a project investigating the teaching and learning of Statistics for student teachers.
All information obtained would be treated confidentially

Please tick (√) the relevant box or fill in the dotted lines

1. Are you : ☐ Male ☐ Female

2. Matric no. : ……………………………..

3. Semester of study : ☐1 ☐2 ☐3 ☐4 ☐5 ☐6

4. Programme of study : ☐ Mathematics education ☐ IT education ☐ Science education & others

5. **The way you would like to learn Statistics.** Please tick (√) the box which best indicates your opinions.

	Statement	S.A.	A	N	D	S.D.
1.	The lecturer gives all the input and the students take down the notes without question					
2.	Need to have discussions between lecturer/students and student/student					
3.	Just have to memorise the facts and figures given by the lecturer					
4.	Do not need to do practical work in the lecture					
5.	The teaching should be interactive and the lecturer's role is just as a facilitator					
6	Need to use the statistical software to avoid the tedious calculations and doing the graphs/charts					
7.	The lecturer should use real life data in examples					
8.	I do not need to understand to understand the statistical concepts and interpretations to pass the course					
9.	Students should be taught how to use statistics effectively to make decisions in real life situations					
10.	Tests and exam questions should focus more on the calculations rather than interpretations					

What are your general opinions about the learning units that you have had experienced recently? 'Do you think it is a good idea to introduce similar learning units into the introductory statistics course? Please explain the reason for your answer

Appendix M

Post- questionnaire for the field experiment (comparison group)

Centre for Science Education, University of Glasgow.

This questionnaire is part of a project investigating the teaching and learning of Statistics for student teachers.
All information obtained would be treated confidentially

Please tick (√) the relevant box or fill in the dotted lines

1. Are you : ☐ Male ☐ Female

2. Matric no. : ....

3. Semester of study : ☐1 ☐2 ☐3 ☐4 ☐5 ☐6

4. Programme of study : ☐ Mathematics education ☐ IT education ☐ Science education & others

5. **The way you would like to learn Statistics**. Please tick (√) the box which best indicates your opinions.

	Statement	S.A.	A	N	D	S.D.
1.	The lecturer gives all the input and the students take down the notes without question					
2.	Need to have discussions between lecturer/students and student/student					
3.	Just have to memorise the facts and figures given by the lecturer					
4.	Do not need to do practical work in the lecture					
5.	The teaching should be interactive and the lecturer's role is just as a facilitator					
6	Need to use the statistical software to avoid the tedious calculations and doing the graphs/charts					
7.	The lecturer should use real life data in examples					
8.	I do not need to understand to understand the statistical concepts and interpretations to pass the course					
9.	Students should be taught how to use statistics effectively to make decisions in real life situations					
10.	Tests and exam questions should focus more on the calculations rather than interpretations					

Appendix N

The structural communication grids test (2) for the experimental and comparison groups

Something for you to do

Use the boxes to answer the following questions. Each box may be used **more than once**. Use the numbers 1,2,3,...,9 to represent the boxes.

1 -0.67	2 0	3 1.0
4 -0.42	5 0.42	6 0.67
7 0.17	8 0.20	9 0.88

Question 1

A boy tosses a fair die a number of times. Each time, he records the face up of the die whether it is 1,2,3,4,5 or 6. What is the relative frequency for '6' that he would expect if he tosses the die 1 000 times?

Box(es) no.: ....

Question 2

Ali obtained 60 % in his mathematics examination. The mathematics teacher told the class that the average mark was 65 %. If the teacher were to convert all the marks into standard scores based on the standard normal distribution, what could be the possible standard standard score for Ali ?

Box(es) no : ....

Question 3

A couple plans to have children. They would like to have a boy to be able to pass on the family name. After some discussion, they decide to continue to have children until they have a boy or until they have 3 children, whichever comes first. What is the probability that they will have a boy among their children ?

Box(es) no : ....

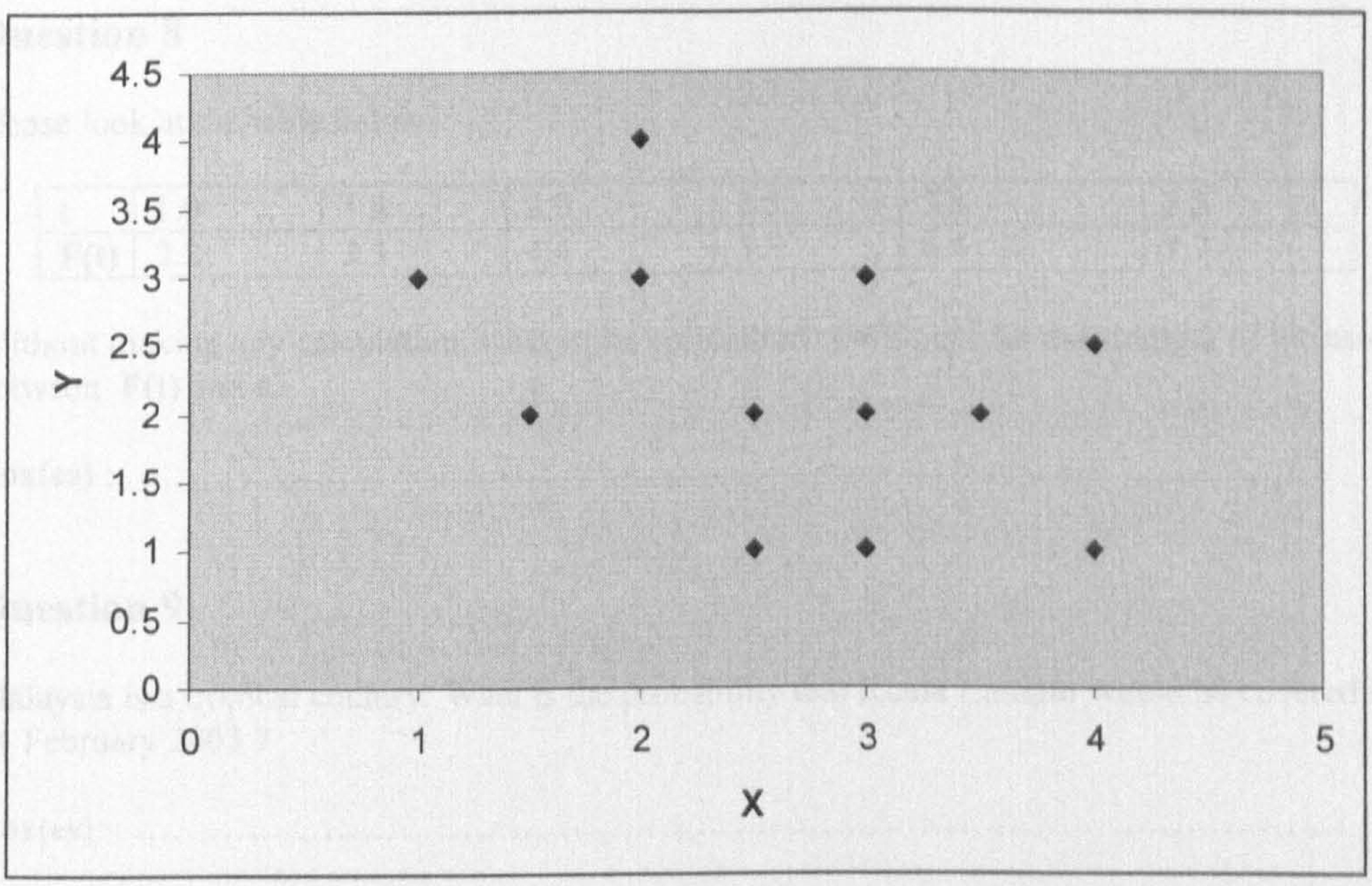
Question 4

Manchester United FC is quoted by a leading bookmaker to have odds of 5 to 1 against winning this season European Champions' League Trophy. What is the probability of Manchester United FC of winning the Trophy ?

Box(es) no : ....

Question 5

Look at the scatterplot below



Values of X are plotted against the values of Y. There seems to be a relationship between X and Y. What could be the possible value for the correlation coefficient r (the value indicating the strength of the relationship) between X and Y.

Box(es) no : ....

Question 6

A schoolgirl tosses three pieces of fair coins simultaneously. She repeats the activity 100 times. Each time, she records the face up of each of the coins whether it is 'head' or 'tail'. Estimate the relative frequency for obtaining at least a 'head' among the three pieces of coins.

Box(es) : ....

Question 7

Malaysia plays Indonesia in a semi final match of the Tiger Cup competition on 27 December 2002 in Jakarta. Based on previous records, it is estimated that the probability that Malaysia would win is 0.18 and for Indonesia to win is 0.32. After 90 minutes, what is the probability that the match would be drawn ?

Box(es) : ....

Question 8

Please look at the table below

t	1.0	1.5	2.0	2.5	3.0	3.5
F(t)	2.2	3.3	4.4	5.5	6.6	7.7

Without making any calculation, what is the correlation coefficient for the strength of the association between **F(t)** and **t**.

Box(es) : ....

Question 9

Malaysia is a tropical country. What is the probability that Kuala Lumpur would be covered in snow on 14 February 2003 ?

Box(es) : ....

Appendix O

The introductory statistics final examination paper for semester II 2002/2003

TMS 1013/TM 1033 INTRODUCTORY STATISTIC

Semester 2 2002/2003 Final Examination Time : 2 hours 30 minutes

Answer ALL Questions.

1. a) The following table shows the examination marks obtained by a group of 70 students

Marks		f	cf
30-39		3	
40-49		12	
50-59		19	
60-69		28	
70-79		6	
80-89		2	

(i) Complete the empty cells in the table above and draw the 'less than' ogive in the grid below.

(ii) By using the ogive, estimate the percentage of those who obtained less than 65 marks.

(iii) Explain the term *median*. From your graph, estimate the nedian value.

(b) The prices of chilly and ladyfinger over one week in the wholesale marke at Tanjong Malim is as follows:

Chilly (RM/kg) 10, 12, 8, 14, 7, 6, 8
Ladyfinger (RM/kg) 2, 3, 3, 2, 4, 2, 2

Compare the prices for both vegetables by using the coefficient of variation and explain your results.

2. (a) In a class of 100 students, 60 are with PKPG background (G), 20 with Matriculation (M), 15 with Diplomas (D) and 5 with STPM (S). A student is selected at random from the class. Calculate the probability of selecting a student from each of the following background:

i) G
ii) G or M
iii) Other than D

(b) A box of identical multi-flavoured sweets contain 60 sweets, of which 20 are chocolate, 30 are strawberry and the remainder is orange. A child picks one sweet and then throws a pair of dice on a smooth table. Let C be the event of getting a chocolate flavoured sweet and S be the event that the two dice show the same face. Calculate the probability, $P(C \cap S)$, that events C and S occurred together.

(c) Explain in one or two sentences the meaning of 'mutually exclusive events'.

(d) Define conditional probability of an event.

e) Ali has five blue and four white marbles in his pocket and four blue and five white marbles in his right pocket. If he transfers one marble at random from his left pocket to his right, what is the probability of him drawing a blue marble from his right pocket?

3. (a) In an experiment of tossing a fair coin twice.

(i) Construct the sample space.
(ii) If X represents a random variable for the number of tail, construct the probability distribution and cumulative probability didtribution for X.
(iii) Find the mean and variance of the random variable X in (ii).

(b) A random variable X has the probability distribution function

$$f(x) = \begin{cases} c\,(2x + 3) & \text{for } x = 0, 1, 2, 3, 4, 5 \\ 0 & \text{elsewhere} \end{cases}$$

(i) Find the value of c
(ii) Draw the graph for the probability function
(iii) Find the value pf $P (2 < X < 4)$

4. (a) A lecturer decides to measure the academic success of a group of 100 students. He defines academic success as the marks scored above one standard deviation from the average. Given that the average score is 54 and the standard deviation is 25,

(i) Calculate the minimum marks for the academic success.
(ii) Construct the 95% confidence interval of the average marks.

(b) The average daily price of palm fruit over 36 days is RM 250 per ton with standard deviation of RM 40. According to previous study, the mean daily price was RM 230 per ton. Test the hypothesis that the average daily price for the current period has increased.

5. (a) An insurance salesperson sells policies to 5 lecturers, all of identical age and in good health. According to actuarial tabled, the probability that a person of this particular nature will survive for another 10 years is 0.7. Find the probability that in 10 years

(i) all five lecturers will survive
(ii) at least 4 lecturers will survive
(iii) only 1 lecturer will survive

(b) According to Road Transport Department, the number of fatal accidents per year is 1 per 1 000 motorist population. Find the probability that in a population of 2 000 motorists there will be

(i) 2 fatal accidents in a year
(ii) between 3 and 6 fatal accidents in 2 years
(iii) fewer than 5 fatal accidents in 2 years

Appendix P

The multiple-choice test on descriptive statistics and probability concepts

Matric No .... Semester......... Program ....

Please try to answer all questions . For each question, please tick the appropriate box which you think might represent the correct answer or your opinion.

Question 1
a) A wooden cube the size of a normal die is painted black on one side and white the other side. With the black side face up, it is then tossed up in the air and lands on a flat surface. Which side is more likely to be faced up ?

□ The black side □ The white side □ No difference

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure,but I suspect it might be □ Just guessing

Question 2
a) There are 22 blue marbles and 28 red marbles in a small black bag. A boy picks out a marble at random without looking. Which marble is he more likely to pick out ?

□ Blue □ Red □ Equal chance of picking out a blue or red

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure,but I suspect it might be □ Just guessing

Question 3
a) The first roll of a fair die results in a '6'.The die is rolled a second time. What is the chance that the second roll also results in a '6' ?

□ 1/6 □ 1/36 □ Slightly more than 1/6

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure,but I suspect it might be □ Just guessing

Question 4
a) A fair coin is tossed four times and 'Tails' appear every time. The coin is then tossed for the fifth time. Which of the following statements is most likely ?

□ 'Tail' is more likely to turn up again
□ 'Head' is more likely to turn up
□ 'Tail' is as likely to turn up as 'Head'

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure,but I suspect it might be □ Just guessing

Question 5
a) In a lucky draw , a customer is asked to pick out a gold coloured counter from one of two bags in order to win a prize. The customer knows that in bag X there are 3 gold coloured counters and 4 silver coloured counters while in bag Y there are 3 gold coloured counters and 3 silver coloured counters. Without looking into the bags, which bag gives the customer the better chance of picking out a gold coloured counter ?

□ Bag X □ Bag Y □ Doesn't matter which bag

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure,but I suspect it might be □ Just guessing

Question 6
a) There are 2 coloured discs ; yellow and white which are marked with numbers as shown in the diagram below. Each disc has a pointer which is spun and points to a number. With which disc is it easier to get a number '1' ?

□ Yellow □ White □ Both discs have the same chance

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure,but I suspect it might be □ Just guessing

Question 7
a) A bag has 6 pieces of fruits : 2 pears, 2 oranges and 2 apples. 3 pieces of fruits are picked one at a time. Each time a fruit is picked , the type of fruit is recorded and it is then put back in the bag. If the first 2 fruits were oranges, what is the third piece likely to be ?

□ A pear □ An orange □ An apple □ All are equally likely/same chance

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure,but I suspect it might be □ Just guessing

Question 8
a) A fair die is rolled four times. Which of the following ordered sequences of results is least likely to occur?

□ 3, 4, 5, 6 □ 2, 5, 5, 2 □ 1, 4, 3, 2 □ All sequences are equally likely

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure,but I suspect it might be □ Just guessing

Question 9
a) Which of the following is not true of probabilities ?

□ If it is impossible for an event to occur, the probability is 0
□ The probability of any event is greater than or equal to 0 but less than or equal to 1
□ For any events X, Y, the probability that one or other of them will occur is the sum of their probabilities ie P(X or Y) = P(X) + P(Y)
□ If the probability an event will occur is p, then the probability it will not occur is 1 – p

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure,but I suspect it might be □ Just guessing

Question 10
a) For the data 2, 3, 4, 4, 5, 7 which of the following is true ?

□ The mean and mode have the same value
□ The mean and median have the same value
□ The mode and median have the same value
□ The mean, mode and median all have the same value

b) How confident are you that you have identified the correct answer ?
□ Very confident □ I cannot be sure,but I suspect it might be □ Just guessing
Question 11
a) For a set of data which contains extreme values, the best measure of location is

□ mean □ median □ mode □ first quartile or third quartile

b) How confident are you that you have identified the correct answer ?
☐ Very confident ☐ I cannot be sure,but I suspect it might be ☐ Just guessing

Question 12
a) Which of the following statements is false ?

☐ The standard deviation of the numbers 6, 6, 6, 6, 6, 6, 6, 6 is 0
☐ The sum of the deviations from the mean is always 0
☐ If the sum of the squared deviations from the mean is divided by n-1, we obtain the sample variance
☐ The sample variance is always greater than the sample standard deviation

b) How confident are you that you have identified the correct answer ?
☐ Very confident ☐ I cannot be sure,but I suspect it might be ☐ Just guessing

Question 13
a) Which of the following statements is true ?

☐ Frequency polygon is a line graph of a cumulative frequency distribution
☐ In a histogram, the width of the rectangles represent the class frequencies
☐ A stem and leaf plot would be most helpful in finding the median
☐ The box plot consists of the first quartile, median and the third quartile

b) How confident are you that you have identified the correct answer ?
☐ Very confident ☐ I cannot be sure,but I suspect it might be ☐ Just guessing

Question 14
a) In order to compare the values of two numbers which belong to different sets of data, we use

☐ the coefficient of variation ☐ z-scores ☐ Chebyshev's theorem ☐ the midrange

b) How confident are you that you have identified the correct answer ?
☐ Very confident ☐ I cannot be sure,but I suspect it might be ☐ Just guessing

Question 15
a) Which of the following does not involve descriptive statistics ?

☐ summarszing data ☐ presenting data ☐ generalising from data ☐ analyzing data

b) How confident are you that you have identified the correct answer ?
☐ Very confident ☐ I cannot be sure,but I suspect it might be ☐ Just guessing

Appendix Q

Comparison of responses to the exploratory study's questionnaire between gender and between programmes of study

Comparisons of responses given between male and female student teachers using chi-square test. The frequencies are given in the form of percentages.

A. Attitudes toward statistics

Statement	G	Pos.	Neu.	Neg.	χ^2	df	Sig.lev
I like to study statistics	M	72.3	27.7	0.0	1.4	1	n.s.
	F	64.3	31.7	3.9			
Statistics is difficult to learn	M	36.9	38.5	24.6	14.4	2	0.001
	F	15.7	54.8	29.6			
I don't like statistics	M	1.5	21.5	76.9	0.1	1	n.s.
	F	4.8	20.0	75.2			
Statistics is easier to learn than mathematics	M	23.1	43.1	33.8	0.3	2	n.s.
	F	20.4	43.0	36.5			
A lot of difficult concepts in statistics	M	44.6	43.1	18.5	2.1	2	n.s.
	F	46.5	41.7	11.7			
Have to work hard to master statistical concepts	M	90.9	7.0	2.2	4.4	1	0.05
	F	84.6	15.4	0.0			
Statistics is a challenging subject	M	85.7	12.2	2.2	1.2	1	n.s.
	F	80.0	15.4	4.6			
Easier to learn statistics using statistics software	M	30.0	41.3	28.7	3.4	2	n.s.
	F	20.0	41.5	38.5			

B. Opinions a bout the introductory statistics course

Statement	G	Pos.	Neu.	Neg.	χ^2	df	p
Easy - Difficult	M	18.5	58.5	23.1	1.99	2	n.s.
	F	27.0	51.3	21.7			
Boring lectures – Interesting lectures	M	69.2	20.0	10.8	10.87	2	0.01
	F	46.1	35.2	18.7			
Heavy workload – Light workload	M	12.3	49.2	38.5	6.05	2	0.05
	F	9.6	34.8	55.6			
Tutorials do help – Tutorials don't help	M	46.2	21.5	32.3	5.46	2	n.s.
	F	47.4	32.6	20.0			
A lot of mathematics Involved – Not mathematical enough	M	33.8	53.8	12.3	6.86	2	0.05
	F	30.4	41.7	27.8			
Have to use statistical software – Don't have to use statistical software	M	47.8	37.4	14.8	9.88	2	0.01
	F	26.2	50.8	23.1			
Too many tests and quizzes – Too few tests and quizzes	M	23.1	61.5	15.4	0.38	2	n.s.
	F	22.2	59.6	18.7			

C. Preferences

Statement	G	Pos.	Neu.	Neg.	χ^2	df	p
Statistics - Algebra	M	26.2	47.7	26.2	10.21	2	0.01
	F	17.0	34.8	48.3			
Statistics - Calculus	M	38.5	35.4	26.2	1.42	2	n.s.
	F	37.8	29.1	33.0			
Statistics – Discrete Mathematics	M	32.3	44.6	23.1	0.71	2	n.s.
	F	37.0	43.9	19.1			
Statistics – English language	M	61.5	18.5	20.0	0.16	2	n.s.
	F	59.1	18.7	22.2			
Statistics – Pedagogical Studies	M	32.3	44.6	23.1	3.06	2	n.s.
	F	29.1	36.5	34.3			

Comparisons of responses given between Mathematics Education (M) and Non-Mathematics Education (N) student teachers using chi-square test. The frequencies are given in the form of percentages.

A. Attitudes toward statistics

Statement	P	Pos.	Neu.	Neg.	χ^2	df	p
I like to study statistics	M	65.6	32.2	2.2	0.06	1	0.807
	N	67.0	28.6	4.5			
Statistics is difficult to learn	M	18.0	56.3	25.7	5.03	2	0.081
	N	24.1	42.9	33.0			
I don't like statistics	M	3.3	18.0	78.7	2.50	1	0.114
	N	5.4	24.1	70.5			
Statistics is easier to learn than mathematics	M	18.6	45.8	35.5	2.30	2	0.317
	N	25.0	38.4	36.6			
A lot of difficult concepts in statistics	M	42.6	45.9	11.4	5.61	2	0.063
	N	51.8	32.1	16.1			
Have to work hard to master statistical concepts	M	87.5	9.8	2.7	0.76	1	0.383
	N	90.7	8.2	1.1			
Statistics is a challenging subject	M	83.6	14.8	1.6	0.24	1	0.628
	N	85.7	9.8	4.5			
Easier to learn statistics using statistics software	M	25.7	49.2	25.1	13.01	2	0.001
	N	31.3	28.6	40.2			

B. Opinions a bout the introductory statistics course

Statement	P	Pos.	Neu.	Neg.	χ^2	df	p
Easy - Difficult	M	23.5	58.5	18.0	6.83	2	0.033
	N	17.7	53.8	28.6			
Boring lectures – Interesting lectures	M	50.8	32.8	16.4	0.23	2	0.892
	N	51.7	30.4	17.9			
Heavy workload – Light workload	M	12.0	38.8	49.2	2.38	2	0.304
	N	7.1	36.6	56.3			
Tutorials do help – Tutorials don't help	M	39.9	34.4	25.7	10.11	2	0.006
	N	58.9	23.2	17.9			
A lot of mathematics Involved –	M	29.5	40.2	30.4	3.52	2	0.172
Not mathematical enough	N	32.2	47.0	20.8			
Have to use statistical software – Don't have to	M	40.4	45.4	14.2	5.45	2	0.066
use statistical software	N	47.3	32.1	20.5			
Too many tests and quizzes – Too few tests and	M	16.4	62.8	20.8	10.62	2	0.005
quizzes	N	32.1	54.5	13.4			

C. Preferences

Statement	P	Pos.	Neu.	Neg.	χ^2	df	p
Statistics - Algebra	M	10.9	44.3	44.8	22.33	2	0.000
	N	32.1	26.8	41.1			
Statistics - Calculus	M	33.9	31.7	34.4	3.63	2	0.163
	N	44.6	28.6	26.8			
Statistics – Discrete Mathematics	M	34.4	51.9	13.7	16.72	2	0.000
	N	38.4	31.3	30.4			
Statistics – English language	M	65.0	15.8	19.1	5.82	2	0.055
	N	50.9	23.2	25.9			
Statistics – Pedagogical Studies	M	31.7	44.8	23.5	16.74	2	0.000
	N	26.8	27.1	45.5			

Appendix R

Relationships between statistics examination scores and student teachers' attitudes toward statistics

Correlation between final exam marks and various statements related to attitudes toward learning statistics, opinions on the introductory statistics course and preferences

Statements	Spearman's ρ
I like to study statistics	-0.024
Statistics is easy to learn	-0.024
I don't like statistics	0.016
Statistics is easier than mathematics	0.033
A lot of difficult concepts in statistics	-0.051
Have to work hard to master statistical concepts	0.122*
Statistics is a challenging subject	0.022
Easier using statistics using statistical .software packages	0.010
Easy-Difficult	0.005
Interesting-Boring	-0.107**
Heavy workload-Light workload	0.013
Tutorials not helpful-Tutorials helpful	0.058
A lot of math involved-Not mathematical enough	0.120**
Have to use statistical.software-Don't have to use statistical software	-0.066
Too many tests/quizzes-Too few tests and quizzes	-0.029
statistics - algebra	0.078
statistics - calculus	-0.128*
statistics - discrete mathematics	0.028
statistics - english language	-0.100*
statistics - pedagogical studies	0.033

- significant at 5% level (*)
- significant at 1% level (**)

Appendix S

Comparison of responses to the pre- questionnaire between gender in the experimental group and the comparison group respectively

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
I like to study statistics	M	12.9	38.6	47.5	1.0	0	0.1	2	n.s.
	F	7.4	45.0	42.8	3.3	1.5			
Statistics is difficult to learn	M	4.0	30.7	51.5	13.9	0	6.9	2	0.05
	F	0.4	21.9	56.1	18.2	3.3			
Statistics is a useful tool in everyday life	M	29.7	52.5	6.9	2.0	0	0.1	2	n.s.
	F	22.7	59.1	16.7	1.1	0.4			
I don't like statistics	M	0	6.9	19.8	55.4	17.8	5.3	3	n.s.
	F	2.6	4.5	31.6	45.4	16.0			
Statistics is easier than other branches of mathematics	M	5.0	12.9	50.5	30.7	1.0	1.0	2	n.s.
	F	0	14.1	50.2	32.0	3.7			
A lot of difficult concepts in Statistics	M	3.7	38.3	44.6	13.0	0	4.3	2	n.s.
	F	3.0	34.7	40.6	19.8	2.0			
Statistics is a challenging subject	M	14.9	59.4	20.8	5.0	0	0.0	2	n.s.
	F	16.0	58.4	24.5	1.1	0			
I enjoy the statistics course that I'm currently studying	M	6.9	27.7	41.6	22.8	1.0	0.6	3	n.s.
	F	6.7	27.9	45.0	17.5	3.0			
It would be easier to learn statistics using software packages	M	21.2	49.4	23.8	5.2	0.4	0.7	2	n.s.
	F	17.8	46.5	27.7	4.0	2.0			
I feel confident about coping with my statistics course	M	2.0	30.7	50.5	13.8	3.0	4.8	2	n.s.
	F	6.7	37.2	45.4	11.5	1.1			

LEGEND:
G-Group M-Male F-Female SA-Strongly Agree A-Agree N-Neutral
D-Disagree SD-Strongly Disagree df-degree of freedom s.l-significant level

(Responses expressed in %, N(Male) = 101, N(Female) = 269)

Attitudes toward learning statistics (Experimental group)

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
I like to study statistics	M	12.3	61.4	26.3	0	0	0.4	2	n.s
	F	14.2	55.0	27.5	3.2	0			
Statistics is difficult to learn	M	5.3	31.6	56.1	7.0	0	3.1	2	n.s.
	F	3.7	33.0	47.7	15.1	0.5			
Statistics is a useful tool in everyday life	M	31.6	52.6	14.0	1.8	0	0.3	2	n.s.
	F	28.0	53.2	18.3	0.5	0			
I don't like statistics	M	0	5.3	15.8	57.9	21.1	0.1	2	n.s.
	F	0	5.5	16.5	56.4	21.6			
Statistics is easier than other branches of mathematics	M	3.5	19.3	49.1	28.1	0	1.0	2	n.s.
	F	4.1	24.3	48.6	22.0	0.9			
A lot of difficult concepts in Statistics	M	3.5	36.8	49.1	7.0	3.5	5.4	2	n.s.
	F	3.2	26.1	47.2	22.5	0.9			
Statistics is a challenging subject	M	10.1	56.0	30.7	3.2	0	0.1	2	n.s.
	F	12.3	52.6	28.1	7.0	0			
I enjoy the statistics course that I'm currently studying	M	6.9	31.7	38.5	22.5	0	1.0	2	n.s.
	F	10.5	31.6	31.6	26.3	0.5			
It would be easier to learn statistics using software packages	M	9.2	52.3	33.0	5.0	0	0.5	2	n.s.
	F	21.1	35.1	38.6	5.3	0.5			
I feel confident about coping with my statistics course	M	8.3	50.0	35.3	5.5	1.0	2.9	2	n.s.
	F	14.0	54.4	22.8	8.8	0			

LEGEND:
G-Group M-Male F-Female SA-Strongly Agree A-Agree N-Neutral
D-Disagree SD-Strongly Disagree df-degree of freedom s.l-significant level

(Responses expressed in %, N(Male) = 57, N(Female) = 218)

Attitudes toward learning statistics (Comparison group)

Word & Statement Pairs	G						χ^2	df	s.l
Easy/Difficult	M	1.0	4.8	50.5	19.8	4.0	10.1	2	0.01
	F	4.1	27.5	57.6	10.8	0			
Boring lectures/Interesting lectures	M	12.9	29.7	35.6	17.8	4.0	15.9	2	0.01
	F	3.3	24.9	44.6	17.8	9.3			
Heavy workload/Light workload	M	6.9	26.7	42.6	17.8	5.9	0.1	2	n.s.
	F	4.5	27.5	44.2	19.3	4.5			
Course too mathematical/ Course less mathematical	M	4.8	31.2	47.6	15.2	1.0	1.0	2	n.s.
	F	6.9	23.8	52.5	15.8	1.1			
Too many tests and quizzes/ Too few tests and quizzes	M	1.0	27.7	47.5	19.8	4.0	5.1	2	n.s.
	F	1.5	10.8	56.5	26.4	4.8			
Real life data rarelys used in examples/ Real life data always used in examples	M	14.9	38.6	28.7	13.9	4.0	1.6	2	0.05
	F	14.5	44.6	27.9	11.5	1.5			
Too many tedious calculations/ Not many calculations involved	M	6.7	55.4	22.3	13.8	2.0	0.3	2	n.s.
	F	4.0	57.4	20.8	16.8	1.0			
Software packages are used in class/ Software packages are not used	M	2.0	13.9	17.8	43.6	22.8	0.8	2	n.s.
	F	4.58	14.15	20.1	43.5	17.8			
Interpretations of statistical results are emphasised/Little emphasis is given	M	3.0	8.9	19.8	54.5	13.9	0.6	2	n.s.
	F	1.9	7.4	20.1	57.6	13.0			
The lecturer shows how statistics is used in daily life/The lecturer does not show how statistics is used in daily life	M	5.0	14.9	25.7	46.3	13.9	6.4	2	n.s.
	F	5.9	15.6	37.2	28.6	12.6			

LEGEND:
G-Group M-Male F-Female df-degree of freedom s.l-significant level

(Responses expressed in %, N(Male) = 101, N(Female) = 269)

Opinions about the introductory statistics course (Experimental group)

Word & Statement Pairs	G						χ^2	df	s.l
Easy/Difficult	M	2.3	21.6	56.0	16.5	3.7	0.9	2	n.s.
	F	1.8	31.6	47.4	19.3	0			
Boring lectures/Interesting lectures	M	7.8	32.1	36.2	18.3	5.5	2.4	2	n.s.
	F	14.0	10.5	38.6	29.8	7.0			
Heavy workload/Light workload	M	3.5	22.8	42.1	28.1	3.5	1.1	2	n.s.
	F	2.3	26.6	46.3	22.5	2.3			
Course too mathematical/ Course less mathematical	M	4.6	37.2	45.0	12.4	0.9	3.1	2	n.s.
	F	1.8	31.6	57.9	8.8	0			
Too many tests and quizzes/ Too few tests and quizzes	M	1.8	7.0	54.4	31.6	5.3	1.2	2	n.s.
	F	0.9	12.8	54.1	28.0	14.1			
Real life data rarely used in examples/ Real life data always used in examples	M	15.8	52.6	22.8	8.8	0	0.2	2	n.s.
	F	17.4	53.7	21.6	6.4	0.9			
Too many tedious calculations/ Not many calculations involved	M	14.0	50.9	26.3	8.8	0	2.2	2	n.s.
	F	6.4	56.4	21.1	14.7	1.4			
Software packages are used in class/ Software packages are not used	M	1.8	12.3	22.8	42.1	21.1	5.1	3	n.s.
	F	5.5	20.6	12.8	42.2	18.8			
Interpretations of statistical results are emphasised/Little emphasis is given	M	1.8	8.8	21.1	49.1	19.3	0.4	3	n.s.
	F	2.3	11.0	22.0	47.7	17.0			
The lecturer shows how statistics is used in daily life/The lecturer does not show how statistics is used in daily life	M	0	10.5	36.8	38.6	14.0	1.7	3	n.s.
	F	5.5	11.5	32.1	35.3	15.6			

LEGEND:
G-Group M-Male F-Female df-degree of freedom s.l-significant level

(Responses expressed in %, N(Male) = 57, N(Female) = 218)

Opinions about the introductory statistics course (Comparison group)

Appendix T

Comparison of responses to the pre- questionnaire between Mathematics Education and Non-Mathematics Education student teachers in the experimental group and the comparison group respectively

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
I like to study statistics	M	8.0	46.7	44.0	1.3	0	0.5	2	n.s
	N	9.2	42.4	44.1	3.1	1.4			
Statistics is difficult to learn	M	0.7	24.0	52.2	20.3	2.7	12.0	2	0.01
	N	4.0	25.3	65.3	4.0	0			
Statistics is a useful tool in everyday life	M	24.4	57.3	16.6	1.4	0.7	0.1	2	n.s.
	N	25.3	57.3	16.0	1.3	0			
I don't like statistics	M	0	5.3	26.7	58.7	9.3	0.7	2	n.s.
	N	2.4	5.1	28.8	45.4	18.3			
Statistics is easier than other branches of mathematics	M	2.7	13.3	54.7	29.3	0	1.2	2	n.s.
	N	1.3	13.9	49.1	32.1	3.6			
A lot of difficult concepts in Statistics	M	4.1	35.9	43.1	16.6	0.3	0.3	2	n.s.
	N	1.3	40.0	45.3	12.0	1.3			
Statistics is a challenging subject	M	10.7	58.7	28.0	2.7	0	2.4	2	n.s.
	N	16.9	58.6	22.4	2.0	0			
I enjoy the statistics course that I'm currently studying	M	4.0	33.3	40.0	20.0	2.7	0.6	2	n.s.
	N	7.5	26.4	41.5	22.2	2.4			
It would be easier to learn statistics using software packages	M	22.4	46.1	26.4	4.4	0.7	4.1	2	n.s.
	N	14.7	58.7	18.7	6.7	1.3			
I feel confident about coping with my statistics course	M	4.0	38.7	46.7	9.3	1.3	0.3	2	n.s.
	N	5.8	34.6	46.8	9.3	1.7			

Attitudes toward learning statistics (Experimental group)

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
I like to study statistics	M	15.2	56.7	25.3	2.8	0	2.0	2	n.s
	N	8.6	55.2	34.5	1.7	0			
Statistics is difficult to learn	M	3.7	32.3	49.8	13.8	0.5	0.4	2	n.s.
	N	5.2	34.5	48.3	12.1	0			
Statistics is a useful tool in everyday life	M	26.3	55.3	17.5	0.9	0	0.5	2	n.s.
	N	37.9	44.8	17.2	0	0			
I don't like statistics	M	0	5.5	16.1	56.7	21.7	0.1	2	n.s.
	N	0	5.2	17.2	56.9	20.7			
Statistics is easier than other branches of mathematics	M	6.9	27.6	43.1	20.7	1.7	2.0	2	n.s.
	N	3.2	22.1	49.0	24.0	1.7			
A lot of difficult concepts in Statistics	M	3.7	27.2	39.8	28.4	0.9	2.1	2	n.s.
	N	1.7	32.8	39.7	22.4	3.4			
Statistics is a challenging subject	M	11.1	53.9	31.8	3.2	0	2.5	2	n.s.
	N	8.6	60.3	24.1	6.9	0			
I enjoy the statistics course that I'm currently studying	M	7.8	31.3	39.2	21.2	0.5	2.9	2	n.s.
	N	6.9	32.8	29.3	31.0	0			
It would be easier to learn statistics using software packages	M	11.1	47.0	35.9	5.5	0.9	2.4	2	n.s.
	N	13.8	55.2	27.6	3.4	0			
I feel confident about coping with my statistics course	M	9.7	51.2	31.3	6.9	0.9	1.9	2	n.s.
	N	8.6	50.0	37.9	3.4	0			

LEGEND:
G-Group M-Maths Ed N-NonMath Ed SA-Strongly Agree A-Agree N-Neutral
D-Disagree SD-Strongly Disagree df-degree of freedom s.l-significant level

(Responses expressed in %, N(Maths Ed) = 217, N(Non-Maths Ed) = 58)

Attitudes toward learning statistics (Comparison group)

Word & Statement Pairs	G						χ^2	df	s.l
Easy/Difficult	M	4.1	27.8	55.3	11.9	1.0	3.8	2	n.s.
	N	0	22.7	57.3	18.7	1.3			
Boring lectures/Interesting lectures	M	5.8	25.4	40.7	19.3	8.8	4.6	2	n.s.
	N	6.7	29.3	48.0	12.0	4.0			
Heavy workload/Light workload	M	6.1	26.8	43.1	19.0	5.1	0.3	2	n.s.
	N	1.7	29.3	46.7	18.7	4.0			
Course too mathematical/	M	1.3	14.7	57.3	26.7	0	16.7	2	0.01
Course less mathematical	N	6.4	32.9	46.8	12.5	1.4			
Too many tests and quizzes/	M	1.7	13.6	55.9	23.7	5.1	3.0	2	n.s.
Too few tests and quizzes	N	0	22.7	46.7	28.0	2.7			
Real life data rarely used in examples/	M	6.7	53.3	25.3	12.0	2.7	0.7	2	n.s.
Real life data always used in examples	N	5.8	56.6	21.0	15.3	1.40.7			
Too many tedious calculations/	M	12.0	37.3	30.7	16.0	4.0	3.4	2	n.s.
Not many calculations involved	N	15.3	44.4	27.5	11.2	1.7			
Software packages are used in class/	M	4.4	13.9	19.7	43.1	19.0	0.3	2	n.s.
Software packages are not used	N	1.7	14.7	18.7	45.3	20.0			
Interpretations of statistical results are	M	2.4	7.1	20.0	58.	12.2	0.4	2	n.s.
emphasised/Little emphasis is given	N	1.3	10.7	20.0	50.7	17.3			
The lecturer shows how statistics is	M	4.0	22.7	34.7	29.3	9.3	2.2	2	n.s.
used in daily life/The lecturer does not	N	6.1	13.6	33.9	32.5	13.9			
show how statistics is used in daily life									

LEGEND:
G-Group M- Mathematics Education N- Non-Mathematics Educatio
SA- Strongly Agree A- Agree N- Neutral D- Disagree SD- Strongly Disagree
df- degrees of freedom s.l.- significant level

(Responses expressed in %,
N(Mathematics Education) = 295 N(Non-Mathematics Education) = 75

Opinions about the introductory statistics course (Experimental group)

Word & Statement Pairs	G						χ^2	df	s.l
Easy/Difficult	M	2.3	25.8	52.1	17.1	2.8	2.9	2	n.s.
	N	1.7	15.5	62.1	17.2	3.4			
Boring lectures/Interesting lectures	M	8.8	24.9	37.3	22.1	6.9	5.1	2	n.s.
	N	10.3	37.9	34.5	15.5	1.7			
Heavy workload/Light workload	M	3.4	32.8	46.6	15.5	1.7		2	n.s.
	N	4.1	36.9	47.9	10.6	0.5			
Course too mathematical/ Course less mathematical	M	0	20.7	39.7	32.8	6.9	7.2	2	0.05
	N	3.2	27.2	47.0	21.2	1.4			
Too many tests and quizzes/ Too few tests and quizzes	M	1.4	9.2	54.4	30.0	5.1	4.8	2	n.s.
	N	0	20.7	53.4	24.1	1.7			
Real life data rarely used in examples/ Real life data always used in examples	M	11.6	47.1	32.6	7.8	0.9	2.5	2	n.s.
	N	14	53.6	24	3.4	0			
Too many tedious calculations/ Not many calculations involved	M	5.2	50.0	24.1	19.0	1.7	2.8	2	n.s.
	N	8.8	56.7	21.7	12.0	0.9			
Software packages are used in class/ Software packages are not used	M	5.5	18.9	14.7	41.5	19.4	0.4	2	n.s.
	N	1.7	19.0	15.5	44.8	19.0			
Interpretations of statistical results are emphasised/Little emphasis is given	M	2.8	12.0	22.6	47.0	15.7	4.8	2	n.s.
	N	0	5.2	19	51.7	24.1			
The lecturer shows how statistics is used in daily life/The lecturer does not show how statistics is used in daily life	M	4.1	12.9	36.4	5.9	10.6	9.2	2	0.05.
	N	5.2	5.2	20.7	36.2	32.8			

LEGEND:
G-Group M- Mathematics Education N- Non-Mathematics Educatio
SA- Strongly Agree A- Agree N- Neutral D- Disagree SD- Strongly Disagree
df- degrees of freedom s.l.- significant level

(Responses expressed in %,
N(Mathematics Education) = 217 N(Non-Mathematics Education) = 58

Opinions about the introductory statistics course (Comparison group)

Appendix U

Comparison of responses to the post- questionnaire between gender in the experimental group and the comparison group respectively

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
The lecturer gives all the input and the students take down the notes without question	M	2.0	7.9	19.8	67.3	3.0	2.3	2	n.s.
	F	3.3	11.5	22.7	59.1	3.3			
Need to have discussions between lecturer/students and student/student	M	39.6	56.4	4.0	0	0	4.8	2	n.s.
	F	33.8	55.0	11.2	0	0			
Just have to memorise the fact and figures given by the lecturer	M	0	9.9	14.8	68.4	6.9	2.8	2	n.s.
	F	0.4	4.8	17.1	67.6	10.0			
Do not need to do practical work in the classroom	M	0	1.0	12.9	74.7	11.9	0.1	2	n.s.
	F	1.5	2.6	10.8	68.8	16.4			
The learning should be interactive and the lecturer's role is just as a facilitator	M	18.8	66.3	14.9	0	0	2.5	2	n.s.
	F	21.9	57.6	19.0	1.5	0			
Need to use the software packages to avoid the tedious calculations and doing the graphs/charts	M	17.8	54.5	23.8	3.0	1.0	2.4	2	n.s.
	F	15.6	48.3	29.7	6.3	0			
The lecturer should use real life data in examples	M	12.9	46.5	37.6	3.0	0	9.3	2	0.05
	F	8.2	35.3	47.2	8.6	0.7			
I do not need to understand the concepts and interpretations to pass the statistics course	M	0	4.0	11.9	58.4	25.7	0.3	2	n.s.
	F	0	4.5	9.3	59.5	26.8			
Students should be taught how to use statistics effectively to make decisions situations	M	29.7	53.5	15.8	1.0	0	8.9	2	0.05
	F	16.0	66.2	16.7	1.1	0			
Tests and exam questions should focus more on the calculations rather than interpretations	M	19.8	39.6	32.7	5.0	3.0	2.6	3	n.s.
	F	14.9	45.0	34.9	4.8	0.4			

LEGEND:
G-Group M- Male F- Female SA-Strongly Agree A-Agree N-Neutral
D-Disagree SD-Strongly Disagree df-degree of freedom s.l-significant level

(Responses expressed in %, N(Male) = 101, N(Female) =269

Opinions on how student teachers like to learn statistics best (Experimental group)

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
The lecturer gives all the input and the students take down the notes without question	M	3.5	15.8	28.1	45.6	7.0	0.8	2	n.s.
	F	2.3	17.4	22.5	54.1	3.7			
Need to have discussions between lecturer/students and student/student	M	27.5	46.3	24.4	1.8	0	1.2	2	n.s.
	F	28.1	38.6	32.3	0.5	0.5			
Just have to memorise the fact and figures given by the lecturer	M	1.8	12.3	21.1	52.6	12.3	0.1	2	n.s.
	F	0	12.4	21.1	54.1	12.4			
Do not need to do practical work in the classroom	M	7.0	1.8	12.3	61.4	17.5	0.1	2	n.s.
	F	0.9	2.8	17.0	59.6	19.7			
The learning should be interactive and the lecturer's role is just as a facilitator	M	24.6	47.4	2.1	7.0	0	0.1	2	n.s.
	F	19.3	51.8	22.0	6.9	0			
Need to use the software packages to avoid the tedious calculations and doing the graphs/charts	M	17.5	47.4	31.6	3.5	0	0.1	2	n.s.
	F	14.7	51.4	28.0	6.0	0			
The lecturer should use real life data in examples	M	12.3	49.1	33.3	3.5	1.8	6.3	2	0.05
	F	8.3	35.3	44.5	11.9	0			
I do not need to understand the concepts and interpretations to pass the statistics course	M	1.8	7.0	15.8	52.6	22.8	0.5	2	n.s.
	F	0	2.8	26.6	45.4	25.2			
Students should be taught how to use statistics effectively to make decisions situations	M	15.8	68.4	15.8	0	0	3.5	2	0.05
	F	13.3	58.7	25.7	1.8	0.5			
Tests and exam questions should focus more on the calculations rather than interpretations	M	24.6	36.8	26.3	7.0	5.3	1.2	3	n.s.
	F	7.8	50.0	33.0	8.7	0.5			

LEGEND:
G-Group M- Male F- Female SA-Strongly Agree A-Agree N-Neutral
D-Disagree SD-Strongly Disagree df-degree of freedom s.l-significant level

(Responses expressed in %, N(Male) =57, N(Female) =218

Opinions on how student teachers like to learn statistics best (Comparison group)

Appendix V

Comparison of responses to the post- questionnaire between Mathematics Education and Non-Mathematics Education student teachers in the experimental group and the comparison group respectively

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
The lecturer gives all the input and the students take down the notes without question	M	5.3	13.3	21.3	58.7	1.3	2.2	2	n.s.
	N	2.4	9.8	22.0	62.0	3.3			
Need to have discussions between lecturer/students and student/student	M	33.3	54.7	12.0	0	0	0.9	2	n.s.
	N	35.9	55.6	8.5	0	0			
Just have to memorise the fact and figures given by the lecturer	M	0.3	5.8	15.9	68.1	9.8	0.8	2	n.s.
	N	0	8.0	18.7	66.3	6.7			
Do not need to do practical work in the classroom	M	1.4	2.0	11.5	68.5	16.6	2.9	2	n.s.
	N	0	2.7	10.7	77.3	9.3			
The learning should be interactive and the lecturer's role is just as a facilitator	M	20.3	59.3	19.0	1.4	0	2.0	2	n.s.
	N	24.0	62.7	13.3	0	0			
Need to use the software packages to avoid the tedious calculations and doing the graphs/charts	M	18.7	42.7	30.7	6.7	1.3	1.5	3	n.s.
	N	15.6	51.9	27.5	5.1	0			
The lecturer should use real life data in examples	M	8.1	36.6	47.5	7.1	0.7	6.7	3	n.s.
	N	14.7	45.3	33.3	6.7	0			
I do not need to understand the concepts and interpretations to pass the statistics course	M	0	4.7	9.5	58.3	27.5	0.7	2	n.s.
	N	0	2.7	12.0	62.7	22.7			
Students should be taught how to use statistics effectively to make decisions situations	M	18.6	61.4	18.6	1.4	0	6.2	2	0.05
	N	24.0	68.0	8.0	0	0			
Tests and exam questions should focus more on the calculations rather than interpretations	M	16.9	43.1	33.8	5.1	1.0	0.6	2	n.s.
	N	13.3	45.3	36.0	4.0	1.3			

LEGEND:
G-Group M- Mathematics Education N- Non-mathematics Education
SA-Strongly Agree A-Agree N-Neutral
D-Disagree SD-Strongly Disagree df-degree of freedom s.l-significant level

(Responses expressed in %,)
N(Mathematics Education) = 295, N(Non-Mathematics Education) = 75

Opinions on how student teachers like to learn statistics best (Experimental group)

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
The lecturer gives all the input and the students take down the notes without question	M	2.8	18.9	22.6	51.2	4.6	2.8	2	n.s.
	N	1.7	10.3	27.6	56.9	3.4			
Need to have discussions between lecturer/students and student/student	M	27.2	44.7	26.7	0.9	0.5	1.0	2	n.s.
	N	29.3	44.8	25.8	0	0			
Just have to memorise the fact and figures given by the lecturer	M	0.5	12.4	21.2	54.4	11.5	0.7	3	n.s.
	N	0	12.1	20.7	51.7	15.5			
Do not need to do practical work in the classroom	M	2.3	2.8	16.1	58.5	20.3	1.0	2	n.s.
	N	1.7	1.7	15.5	65.5	15.5			
The learning should be interactive and the lecturer's role is just as a facilitator	M	21.2	47.9	24.0	5.9	0	3.8	2	n.s.
	N	17.2	62.1	13.8	6.9	0			
Need to use the software packages to avoid the tedious calculations and doing the graphs/charts	M	15.7	48.8	30.0	5.5	0	0.8	2	n.s.
	N	13.8	56.9	24.1	5.2	0			
The lecturer should use real life data in examples	M	8.8	38.7	41.9	10.1	0.5	0.2	3	n.s.
	N	10.3	36.2	43.1	10.3	0			
I do not need to understand the concepts and interpretations to pass the statistics course	M	0	3.7	24.9	48.8	22.6	0.3	2	n.s.
	N	1.7	3.4	22.4	39.7	32.8			
Students should be taught how to use statistics effectively to make decisions situations	M	15.2	58.1	24.9	1.4	0.5	3.3	2	n.s.
	N	8.6	70.7	19.0	1.7	0			
Tests and exam questions should focus more on the calculations rather than interpretations	M	11.5	49.8	28.6	8.8	1.4	4.6	3	n.s.
	N	10.5	38.1	43.1	6.9	1.7			

LEGEND:
G-Group M- Mathematics Education N- Non-Mathematics Education
SA-Strongly Agree A-Agree N-Neutral
D-Disagree SD-Strongly Disagree df-degree of freedom s.l-significant level

(Responses expressed in %,)
N(Mathematics Education) = 217, N(Non-Mathematics Education) = 58

Opinions on how student teachers like to learn statistics best (Comparison group)

Appendix W

Comparison of responses to the pre and post questionnaires between the field dependency categories in the experimental group and the comparison group respectively

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
I like to study statistics	D	8.0	34.7	54.7	2.7	0	6.0	2	0.05
	N	8.0	42.0	44.3	3.4	2.3			
	I	6.2	56.9	30.8	3.	3.1			
Statistics is difficult to learn	D	0	35.4	42.5	18.5	4.6	5.7	4	n.s.
	N	1.1	23.9	53.4	19.3	2.3			
	I	4.0	20.0	60.0	14.7	1.3			
Statistics is a useful tool in everyday life	D	21.3	53.3	25.3	0	0	2.1	4	n.s.
	N	25.0	54.5	17.0	2.3	1.1			
	I	30.8	53.8	13.8	1.5	0			
I don't like statistics	D	4.6	6.2	23.1	46.2	20.0	0.8	4	n.s.
	N	3.4	6.8	31.8	43.2	14.8			
	I	0	8.0	30.7	46.7	14.7			
Statistics is easier than other branches of mathematics	D	1.3	9.3	49.3	37.3	2.7	4.4	4	n.s.
	N	1.1	13.6	44.3	37.5	3.4			
	I	3.1	20.0	43.1	29.2	4.6			
A lot of difficult concepts in Statistics	D	5.7	40.9	45.5	5.7	2.3	7.5	4	n.s.
	N	1.3	38.7	42.7	17.3	0			
	I	6.2	23.1	49.2	21.5	0			
Statistics is a challenging subject	D	16.9	61.5	20.0	1.5	0	1.2	2	n.s.
	N	12.5	59.1	28.4	0	0			
	I	14.7	57.3	24.0	4.0	0			
I enjoy the statistics course that I'm currently studying	D	2.7	16.0	50.7	28.0	2.7	10.7	4	0.05
	N	6.8	13.6	54.5	25.0	0			
	I	4.6	33.8	33.8	23.1	4.6			
It would be easier to learn statistics using software packages	D	23.1	43.1	27.7	6.2	0	1.3	4	n.s.
	N	20.5	38.5	34.1	4.5	2.3			
	I	10.7	48.0	32.0	8.0	1.3			
I feel confident about coping with my statistics course	D	8.0	26.1	44.3	18.2	3.4	3.5	4	n.s.
	N	0	37.3	49.3	10.7	2.7			
	I	7.7	36.9	43.1	10.8	1.5			

LEGEND:
G-Group D-Field Dependent N-Field Neutral I-Field Independent
SA-Strongly Agree A-Agree N-Neutral D-Disagree SD-Strongly Disagree
df-degree of freedom s.l-significant level

(Responses expressed in %,
N(F. Dependent) = 75, N(F. Neutral) = 88, N(F. Independent) = 65

Attitudes toward learning statistics (Experimental group)

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
I like to study statistics	D	8.9	37.5	50.0	3.6	0	4.4	2	n.s.
	N	10.6	46.8	40.4	2.1	0			
	I	14.8	50.8	34.4	0	0			
Statistics is difficult to learn	D	1.8	42.9	48.2	7.1	0	0.9	2	n.s.
	N	3.3	39.3	47.5	9.8	0			
	I	8.5	27.7	53.2	10.6	0			
Statistics is a useful tool in everyday life	D	21.4	62.5	16.1	0	0	2.6	4	n.s.
	N	31.9	55.3	12.8	0	0			
	I	29.5	50.8	19.7	0	0			
I don't like statistics	D	0	4.9	13.1	57.4	24.6	7.1	4	n.s.
	N	0	6.4	19.1	48.9	25.5			
	I	0	1.8	8.9	73.2	16.1			
Statistics is easier than other branches of mathematics	D	1.6	19.7	52.5	26.2	0	5.6	4	n.s.
	N	6.4	17.0	53.2	23.4	0			
	I	1.8	37.5	39.3	21.4	0			
A lot of difficult concepts in Statistics	D	3.3	29.5	41.0	26.2	0	5.2	4	n.s.
	N	7.1	19.6	55.4	16.1	1.8			
	I	2.1	21.3	61.7	12.8	2.1			
Statistics is a challenging subject	D	8.9	55.4	32.1	3.6	0	0.4	2	n.s.
	N	8.2	55.7	34.4	1.6	0			
	I	10.6	48.9	36.2	4.3	0			
I enjoy the statistics course that I'm currently studying	D	5.3	12.5	51.8	17.8	12.5	8.4	2	n.s.
	N	4.2	14.9	53.2	19.1	8.5			
	I	16.4	21.3	34.4	18.0	9.8			
It would be easier to learn statistics using software packages	D	3.6	51.8	44.6	0	0	0.8	2	n.s.
	N	9.8	39.3	37.7	11.5	1.6			
	I	8.5	38.3	42.6	10.6	0			
I feel confident about coping with my statistics course as I do about other courses	D	8.2	30.8	47.8.8	9.9	3.3	1.8	4	n.s.
	N	12.8	28.9	47.7	10.6	0			
	I	14.3	33.6	43.2	8.9	0			

LEGEND:
G-Group D-Field Dependent N-Field Neutral I-Field Independent
SA-Strongly Agree A-Agree N-Neutral D-Disagree SD-Strongly Disagree
df-degree of freedom s.l-significant level

(Responses expressed in %,
N(F. Dependent) = 56, N(F. Neutral) = 47, N(F. Independent) = 61

Attitudes toward learning statistics (Comparison group)

Word & Statement Pairs	G						χ²	df	s.l
Easy/Difficult	D	4.6	23.1	50.8	20.	1.5	3.1	4	n.s.
	N	0	30.7	57.3	10.7	1.3			
	I	4.5	28.4	55.7	11.4	0			
Boring lectures/Interesting lectures	D	12.0	28.0	37.3	22.7	0	1.4	4	n.s.
	N	12.5	25.0	39.8	20.5	2.3			
	I	10.8	20.0	43.1	21.5	4.6			
Heavy workload/Light workload	D	6.2	29.2	33.8	23.1	7.7	4.7	4	n.s.
	N	2.3	26.1	45.5	20.5	5.7			
	I	1.3	21.3	49.3	24.0	4.0			
Course too mathematical/ Course less mathematical	D	8.0	32.0	49.4	9.3	1.3	2.8	4	n.s.
	N	4.5	29.5	51.1	12.5	2.3			
	I	3.1	32.3	44.6	20.0	0			
Too many tests and quizzes/ Too few tests and quizzes	D	2.7	17.3	53.3	24.0	2.7	3.9	4	n.s.
	N	3.4	8.0	58.0	23.9	6.8			
	I	0	15.4	47.7	33.8	3.1			
Real life data rarely used in examples/ Real life data always used in examples	D	9.1	35.2	35.2	18.2	2.3	6.4	4	n.s.
	N	6.7	53.3	24.0	13.3	2.7			
	I	15.4	47.7	20.0	12.3	4.6			
Too many tedious calculations/ Not many calculations involved	D	5.3	42.7	37.3	14.7	0	1.8	4	n.s.
	N	7.7	33.8	40.0	16.9	1.5			
	I	5.7	34.1	45.5	12.5	2.3			
Software packages are used in class/ Software packages are not used	D	0	10.7	32.0	28.0	29.3	4.8	4	n.s.
	N	3.4	14.8	22.7	33.0	26.1			
	I	4.6	4.6	33.8	30.8	26.2			
Interpretations of statistical results are emphasised/Little emphasis is given	D	3.1	10.8	41.5	35.4	9.2	4.8	4	n.s.
	N	3.4	4.5	50.0	30.7	11.4			
	I	2.7	14.7	46.7	30.7	5.3			
The lecturer shows how statistics is used in daily life/The lecturer does not show how statistics is used in daily life	D	6.8	13.6	42.0	31.8	5.7	5.7	4	n.s.
	N	4.0	22.7	42.7	24	6.7			
	I	12.3	23.1	32.3	26.2	6.2			

LEGEND:
G-Group D- Field Dependent N- Field Neutral I- Field Independent
SA- Strongly Agree A- Agree N- Neutral D- Disagree SD- Strongly Disagree
df- degrees of freedom s.l.- significant level

(Responses expressed in %,
N(Field Dependent) = 75 N(Field Neutral) = 88 N(Field Independent) = 65

Opinions about the introductory statistics course (Experimental group)

Word & Statement Pairs	G						χ^2	df	s.l
Easy/Difficult	D	1.8	21.4	50.0	21.4	5.4	6.7	4	n.s.
	N	1.6	27.9	45.9	21.3	3.3			
	I	0	29.8	61.7	8.5	0			
Boring lectures/Interesting lectures	D	14.8	24.6	27.9	23.0	9.8	5.4	4	n.s.
	N	8.9	23.2	30.4	25.0	12.5			
	I	10.6	14.9	46.8	25.5	2.1			
Heavy workload/Light workload	D	7.1	33.9	46.4	12.5	0	0.7	4	n.s.
	N	0	38.3	59.6	2.1	0			
	I	3.3	38.1	49.8	8.2	1.6			
Course too mathematical/ Course less mathematical	D	3.6	32.1	44.6	19.6	0	14.8	4	0.01
	N	0	31.9	59.6	8.5	0			
	I	1.6	27.9	32.8	36.1	1.6			
Too many tests and quizzes/ Too few tests and quizzes	D	1.8	10.7	51.8	28.6	7.1	1.4	4	n.s.
	N	2.1	6.4	59.6	31.9	0			
	I	0	9.8	47.5	34.4	8.2			
Real life data rarely used in examples/ Real life data always used in examples	D	7.1	51.8	23.2	16.1	1.8	6.6	4	n.s.
	N	12.8	44.7	36.2	4.3	2.1			
	I	19.7	4.2	23.0	8.2	0			
Too many tedious calculations/ Not many calculations involved	D	5.4	36.1	34.4	11.5	1.6	6.0	4	n.s.
	N	10.6	31.9	51.1	6.4	0			
	I	5.4	32.1	44.6	16.1	1.8			
Software packages are used in class/ Software packages are not used	D	0	7.1	28.6	46.4	17.9	4.6	4	n.s.
	N	2.1	8.5	42.6	25.5	21.3			
	I	4.9	4.9	24.6	31.1	34.4			
Interpretations of statistical results are emphasised/Little emphasis is given	D	4.9	9.8	11.5	55.7	18.0	3.9	4	n.s.
	N	2.1	10.6	21.3	51.1	14.9			
	I	3.6	14.3	23.2	42.9	16.1			
The lecturer shows how statistics is used in daily life/The lecturer does not show how statistics is used in daily life	D	3.6	14.3	41.1	39.3	1.8	1.8	4	n.s.
	N	6.4	14.9	40.4	27.7	10.6			
	I	6.6	19.7	42.6	26.2	4.9			

LEGEND:
G-Group D- Field Dependent N- Field Neutral I- Field Independent
SA- Strongly Agree A- Agree N- Neutral D- Disagree SD- Strongly Disagree
df- degrees of freedom s.l.- significant level

(Responses expressed in %,
N(Field Dependent) = 56 N(Field Neutral) = 47 N(Field Independent) = 61

Opinions about the introductory statistics course (Comparison group)

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
The lecturer gives all the input and the students take down the notes without question	D	1.3	18.7	26.7	46.7	6.7	2.8	4	n.s.
	N	4.5	22.7	30.7	40.9	1.1			
	I	4.6	24.6	26.2	41.5	3.1			
Need to have discussions between lecturer/students and student/student	D	40.0	60.0	0	0	0	12.7	4	0.05
	N	28.4	60.2	11.4	0	0			
	I	38.7	48.0	13.1	0	0			
Just have to memorise the fact and figures given by the lecturer	D	0	2.7	24.0	64.0	9.3	2.1	4	n.s.
	N	0	4.5	25.0	58.0	12.5			
	I	0	6.1	23.1	64.6	6.1			
Do not need to do practical work in the classroom	D	0	1.5	17.3	66.7	14.7	3.3	4	n.s.
	N	1.1	5.7	23.9	56.8	12.5			
	I	3.0	6.2	16.9	58.5	15.4			
The learning should be interactive and the lecturer's role is just as a facilitator	D	16.0	45.3	29.3	8.7	1.3	1.5	6	n.s.
	N	15.9	46.6	29.5	8.0	0			
	I	15.4	41.5	36.9	6.2	0			
Need to use the software packages to avoid the tedious calculations and doing the graphs/charts	D	17.3	38.7	33.3	9.3	1.3	2.7	6	n.s.
	N	15.9	40.9	29.5	13.6	0			
	I	13.8	49.2	29.2	7.7	0			
The lecturer should use real life data in examples	D	6.7	45.3	37.3	10.7	0	5.6	4	n.s.
	N	11.4	39.8	46.6	1.1	1.1			
	I	10.8	29.2	50.8	7.7	1.5			
I do not need to understand the concepts and interpretations to pass the statistics course	D	2.7	2.7	20.0	48.0	26.7	11.1	4	0.05
	N	3.4	10.2	8.0	52.3	26.1			
	I	4.6	15.4	13.8	46.2	20.0			
Students should be taught how to use statistics effectively to make decisions situations	D	21.3	60.0	18.7	0	0	4.3	4	n.s.
	N	18.2	56.8	21.6	3.4	0			
	I	16.9	49.2	32.3	1.5	0			
Tests and exam questions should focus more on the calculations rather than interpretations	D	12.0	44.0	33.3	8.0	2.7	3.1	6	n.s.
	N	11.4	45.5	35.2	6.8	1.1			
	I	20.0	40.0	32.3	7.7	0			

LEGEND: (Experimental Group)
G- Group D- Field Dependent N- Field Neutral I- Field Independent
SA- Strongly Agree A- Agree N- Neutral D- Disagree SD- Strongly Disagree
df- degree of freedom s.l- significant level

(Responses expressed in %,)
N(Field Dependent) = 75 N(Field Neutral) = 88 N(Field Independent) = 65

Statement	G	SA	A	N	D	SD	χ^2	df	s.l
The lecturer gives all the input and the students take down the notes without question	D	3.3	14.8	14.8	60.7	6.6	6.2	4	n.s.
	N	3.6	25.0	23.2	46.4	1.8			
	I	2.1	29.8	21.3	42.6	4.3			
Need to have discussions between lecturer/students and student/student	D	57.4	41.0	0	1.7	0	1.5	2	0.05
	N	55.3	42.6	2.1	0	0			
	I	47.5	47.5	1.6	1.6	1.6			
Just have to memorise the fact and figures given by the lecturer	D	0	9.8	14.3	71.4	5.4	3.3	2	n.s.
	N	0	10.6	14.9	57.4	17.0			
	I	1.6	4.9	31.1	52.5	9.8			
Do not need to do practical work in the classroom	D	1.8	0	8.9	76.8	12.5	8.9	4	n.s.
	N	4.3	6.4	4.3	63.8	21.3			
	I	1.6	1.6	21.3	50.8	24.6			
The learning should be interactive and the lecturer's role is just as a facilitator	D	26.8	46.4	17.9	.8.9	0	6.5	4	n.s.
	N	21.3	51.1	21.3	6.4	0			
	I	19.7	34.4	37.7	8.2	0			
Need to use the software packages to avoid the tedious calculations and doing the graphs/chart	D	8.9	53.6	35.7	1.8	0	3.8	4	n.s.
	N	17.0	42.6	34.0	6.4	0			
	I	16.4	37.7	36.1	9.8	0			
The lecturer should use real life data in examples	D	7.1	44.6	39.3	8.9	0	2.3	4	n.s.
	N	10.6	38.3	40.4	10.6	0			
	I	3.3	37.7	42.6	14.8	1.6			
I do not need to understand the concepts and interpretations to pass the statistics course	D	0	1.8	5.4	58.9	33.9	5.1	4	0.05
	N	0	2.1	10.6	53.2	34.0			
	I	0	6.6	14.8	50.8	27.9			
Students should be taught how to use statistics effectively to make decisions situations	D	32.1	53.6	12.5	0	1.8	3.7	4	n.s.
	N	34.0	48.9	14.9	2.1	0			
	I	19.7	60.7	18.0	1.6	0			
Tests and exam questions should focus more on the calculations rather than interpretations	D	3.6	35.7	46.4	10.7	3.6		6	n.s.
	N	8.5	42.6	31.9	14.9	2.1			
	I	14.8	47.5	31.1	6.6	0			

LEGEND: (Comparisdon Group)
G- Group D- Field Dependent N- Field Neutral I- Field Independent
SA- Strongly Agree A- Agree N-Neutral D- Disagree SD- Strongly Disagree
df- degree of freedom s.l-significant level

(Responses expressed in %,)
N(Field Dependent) = 56 N(Field Neutral) = 47 N(Field Independent) = 61

Appendix X

Raw data: from the exploratory study

M	P	S	EM	G	SM	HT	DT	A1	A2	A3	A4	A5	A6	A7	A8	O1	O2	O3	O4	O5	O6	O7	P1	P2	P3	P4	P5
4121	1	5	54	1	2.5	12	8	3	3	4	3	3	1	2	3	3	3	4	2	3	2	3	3	2	2	2	3
4128	1	5	77	2	1.8	12	8	2	3	5	3	3	1	1	5	3	3	3	1	3	2	3	4	4	2	2	3
4134	1	5	63	1	5	13	8	2	3	4	3	3	2	2	3	3	2	4	2	3	3	4	5	5	5	5	5
4145	1	5	70	2	3.5	12	8	3	3	4	4	2	2	2	4	3	4	4	2	4	1	3	5	5	2	3	5
4148	1	5	61	2	-0.7	19	8	4	4	2	4	3	2	3	3	2	4	3	2	4	3	3	5	5	4	4	5
4157	1	5	84	2	-0.3	13	8	2	3	4	4	2	1	2	2	3	2	4	1	4	2	4	5	5	3	2	2
4227	3	5	62	2	-0.5	11	9	1	4	3	4	2	1	2	3	2	4	5	1	2	1	3	2	3	5	5	4
4233	3	5	78	2	-1.2	14	9	1	4	4	5	1	3	1	4	1	3	5	3	5	1	3	5	5	5	2	4
4246	3	5	75	2	0.3	13	8	3	4	3	4	3	1	1	1	2	3	3	4	5	1	3	3	3	3	2	3
4267	3	5	56	2	-1.8	11	8	2	2	4	2	2	2	2	4	4	1	3	3	3	5	3	2	5	3	3	2
4269	3	5	80	2	5	19	8	1	4	4	4	2	2	2	4	4	2	5	3	5	2	2	4	4	2	1	1
4274	3	5	22	2	-2.2	11	9	3	4	3	4	2	1	1	2	3	1	1	1	3	1	3	2	1	3	5	5
6616	1	3	40	2	0.8	14	8	3	5	4	5	1	1	1	2	1	1	1	1	1	5	5	3	5	1	5	1
6674	1	3	48	2	1.5	15	8	3	4	3	3	4	2	2	2	3	3	4	1	4	1	4	5	1	4	2	2
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5887	2	4	67	2	-2.8	6	6	4	4	2	4	2	2	2	2	5	1	1	5	5	4	3	2	5	3	2	3
6379	1	3	65	2	2	3	6	3	4	4	4	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3
6685	1	3	33	2	3	5	6	3	3	4	2	3	4	4	5	3	2	4	3	4	3	3	2	4	2	2	1
6713	1	3	49	1	-1.2	5	6	2	3	4	3	2	2	3	3	3	4	3	5	3	3	3	3	1	3	1	1
7320	1	2	82	2	0.8	5	5	1	2	4	3	2	1	1	2	3	1	2	5	2	2	2	3	3	2	1	1
7341	1	2	67	2	-3.2	3	2	2	3	4	4	2	1	2	2	3	3	4	1	4	3	2	5	5	3	1	5
7636	1	2	68	2	5	5	6	2	3	4	4	2	1	1	1	4	1	4	3	5	2	2	5	5	3	1	3
7645	1	2	79	2	5	3	6	3	4	2	4	2	2	1	1	2	4	2	5	4	4	2	5	4	4	2	4
7653	1	2	43	2	-3.8	5	6	2	3	5	4	2	1	1	4	3	1	5	3	3	3	3	3	3	3	1	1
7765	1	2	73	1	1.7	4	6	2	4	4	4	2	1	3	3	2	3	4	1	2	3	3	3	3	3	3	3
7887	1	2	22	2	-1.2	4	4	2	3	4	3	3	1	2	3	3	3	4	2	2	2	3	3	2	3	4	4
7888	1	2	86	2	4.3	6	6	2	3	5	3	2	2	2	3	3	3	3	1	2	2	3	4	4	2	1	3
8992	1	2	38	2	-3.8	6	5	1	3	5	3	3	1	2	4	3	2	3	3	5	3	2	5	5	1	1	3

Appendix Y

Raw data from the field experiment: experimental group

M	G	S	P	a1	a2	a3	a4	a5	a6	a7	a8	a9	at	o1	o2	o3	o4	o5	o6	o7	o8	o9	ot
6417	2	5	1	1	2	1	3	2	1	1	1	1	2	2	1	3	2	3	1	1	3	1	1
6489	1	5	2	1	1	1	3	1	3	2	1	1	1	3	2	2	3	3	1	3	1	1	3
6501	2	5	2	1	2	1	2	2	1	1	1	1	1	1	2	2	1	1	2	1	1	1	1
6613	2	5	1	2	3	1	2	3	1	1	1	1	2	2	2	2	2	2	2	1	1	2	2
6660	2	5	1	2	2	1	3	2	1	2	1	1	2	1	2	2	2	2	2	3	2	2	2
6390	1	5	1	1	1	1	3	2	2	1	1	1	1	2	1	1	2	2	2	1	3	1	1
6637	2	5	1	1	1	2	3	1	2	2	1	1	1	3	1	2	1	2	3	1	3	1	1
6655	2	5	1	1	3	1	3	2	2	1	1	2	2	2	2	1	2	2	1	1	1	1	1
6415	1	5	1	1	1	1	3	1	3	1	1	1	1	2	1	2	1	2	1	1	1	1	1
5162	1	6	2	1	2	1	2	2	1	1	1	1	2	1	1	2	1	1	1	1	1	1	1
6483	1	5	2	2	1	1	2	3	1	3	1	1	3	1	3	1	3	2	1	3	1	1	3
6516	2	5	1	1	1	1	3	2	1	1	1	1	1	1	1	2	1	1	1	3	3	1	1
6411	1	5	1	1	1	1	2	2	1	1	1	1	1	2	2	1	1	2	2	1	2	2	1
6490	1	5	2	1	2	1	3	2	2	1	1	1	1	2	2	2	3	2	1	1	1	1	2
6683	2	5	1	2	1	1	3	2	2	1	1	1	2	2	1	2	1	1	1	1	2	1	1
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6388	2	5	1	1	2	1	3	2	1	1	1	1	1	2	1	1	1	2	1	1	3	2	1
5154	1	6	2	1	2	1	3	2	2	2	1	1	1	2	1	1	2	1	1	1	1	1	1
6642	2	5	1	1	1	2	3	2	1	1	1	1	1	2	1	1	2	2	1	1	2	1	1
6657	2	5	1	1	2	1	2	2	2	1	1	2	3	2	3	1	3	2	1	1	3	1	1
6397	1	5	1	1	1	1	3	1	3	1	1	1	1	3	1	1	1	1	1	3	2	1	1
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6413	2	5	1	2	2	1	2	2	1	1	1	1	2	2	1	1	1	2	1	1	3	1	1
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6890	1	5	2	1	3	1	3	2	1	1	1	1	2	1	2	3	3	2	2	1	3	1	1
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6872	1	5	2	2	2	1	2	2	3	1	1	1	2	3	3	3	2	1	1	1	3	3	1
6879	1	5	2	1	2	1	3	2	2	1	1	1	2	2	1	3	3	3	2	1	1	1	1
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6627	2	5	1	1	2	1	3	2	1	1	1	1	2	2	2	2	2	2	1	1	1	1	2
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6502	2	5	2	1	2	1	3	2	2	1	1	2	1	2	1	1	2	1	1	1	3	1	1
6395	1	5	1	1	1	1	3	2	2	2	1	1	1	2	1	3	2	2	1	1	3	1	1
6667	2	5	1	1	1	1	3	1	2	1	1	1	1	3	1	1	2	2	1	3	3	1	1
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6668	2	5	1	1	1	1	3	1	3	2	1	1	1	3	1	1	3	3	1	1	3	2	3
6916	2	5	2	1	1	1	3	2	2	1	1	1	1	3	3	3	3	2	3	3	1	3	3
6380	2	5	1	2	2	2	3	2	2	1	1	1	1	3	2	3	3	2	2	1	1	1	2
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5928	2	6	2	1	2	1	3	2	2	1	1	1	1	3	1	2	3	3	2	1	1	2	1
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6622	2	5	1	1	2	1	3	3	1	1	2	1	2	2	1	2	3	3	2	1	2	3	1
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6623	2	5	1	1	2	1	3	2	2	2	2	1	1	2	2	2	1	2	1	1	2	2	1
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6917	2	5	2	2	3	2	2	3	2	1	2	1	2	2	2	3	2	2	3	1	1	1	3
6491	2	5	2	2	2	1	3	2	2	2	2	1	1	3	1	1	3	1	1	1	2	1	3
6475	1	5	2	1	2	1	3	2	1	2	2	1	2	2	2	2	2	3	2	2	1	2	2
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6174	2	5	2	2	2	1	2	1	1	1	2	1	2	2	1	1	2	1	1	1	1	1	1
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6495	2	5	2	1	2	1	3	2	1	1	2	1	2	1	1	2	2	2	1	1	2	1	1
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6640	2	5	1	2	3	1	2	3	1	1	2	1	1	1	3	2	1	2	1	2	3	1	1
6643	2	5	2	2	3	2	3	3	2	1	2	1	1	1	2	1	2	2	1	2	1	1	1
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6383	2	5	1	2	2	2	3	1	1	2	2	1	2	1	2	3	1	2	2	1	2	1	1
6877	2	5	2	2	2	1	2	3	2	1	2	3	3	2	1	3	3	2	1	3	1	1	1
6414	2	5	1	2	2	2	2	3	1	1	2	1	2	2	1	1	2	2	2	1	2	2	1
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6876	2	5	2	2	3	1	3	3	2	1	2	1	1	2	1	1	2	3	1	2	1	1	1
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6919	2	5	2	2	2	1	2	2	1	1	2	1	2	2	2	2	2	2	2	2	1	2	2
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5835	2	6	2	2	3	2	1	2	1	1	3	1	3	2	2	2	2	3	3	3	1	3	2
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M	G	S	EM	SM	HF	P	s1	s2	s3	s4	s5	s6	s7	s8	s9	st
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11825	2	2	66	6	14	1	1	1	3	3	1	1	2	3	2	1
13092	1	1	82	4	14	1	1	1	2	3	1	1	2	3	1	1
10646	2	2	80	4	14	1	3	1	3	3	2	1	2	2	1	1
8738	1	4	55	5	14	1	2	1	3	3	1	2	1	2	2	1
10656	2	2	73	3	14	1	3	1	3	3	2	2	2	3	2	1
10815	2	2	70	2	14	1	2	1	3	3	2	3	3	3	1	1
10858	2	2	87	3	15	1	3	1	3	3	1	3	2	2	1	1
8509	1	4	66	6	15	2	3	1	3	3	1	1	1	3	1	3
10788	2	2	69	5	16	1	3	1	3	3	2	1	2	3	1	1
10631	2	2	65	4	16	1	3	1	3	3	2	2	2	3	1	1
10819	2	2	79	6	17	1	2	1	3	2	1	1	2	3	1	2
10809	2	2	54	4	17	1	1	1	3	1	1	2	1	3	1	2

Appendix Z

Raw data from the field experiment: comparison group

M	G	S	P	a1	a2	a3	a4	a5	a6	a7	a8	a9	at	o1	o2	o3	o4	o5	o6	o7	o8	o9	ot
6891	1	5	2	2	2	1	2	3	1	1	2	2	2	2	3	3	2	3	1	1	1	2	1
6880	2	5	2	2	2	1	3	2	3	1	3	1	2	2	1	2	2	2	1	1	1	1	1
6689	2	5	1	2	3	1	3	3	2	1	2	1	2	2	2	1	3	3	1	1	3	1	1
6703	2	5	1	2	2	1	3	2	3	2	1	1	1	3	1	1	1	2	1	3	3	2	1
6900	2	5	2	2	2	1	3	3	1	1	2	1	1	2	1	3	2	2	1	1	1	1	1
6707	2	5	1	2	3	1	1	3	1	1	3	2	2	1	3	2	1	2	1	1	1	1	1
6518	2	5	3	1	2	2	3	2	2	1	1	2	1	1	1	2	1	2	1	2	1	1	2
6874	2	5	2	2	1	1	2	2	2	1	2	1	2	2	3	3	2	2	1	2	1	1	1
6676	2	5	1	1	2	1	3	2	2	1	2	1	1	3	2	1	1	3	1	1	2	2	1
5809	1	6	3	2	1	1	2	1	2	2	1	3	1	1	2	2	2	1	2	2	1	1	2
6904	2	5	2	2	3	1	2	3	1	1	2	1	2	2	3	3	2	2	1	3	2	1	2
6682	2	5	1	2	3	1	2	2	1	1	2	1	1	1	1	1	2	2	1	1	3	3	1
6896	1	5	2	2	2	1	3	1	1	1	3	1	2	2	2	2	3	2	1	1	3	2	1
6894	1	5	2	2	2	1	3	3	1	1	3	1	2	3	1	2	3	2	1	1	1	1	1
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6835	2	5	3	2	2	1	3	1	3	1	3	1	1	2	3	2	3	1	3	1	1	3	1
6934	2	5	2	2	3	1	2	1	1	1	2	1	1	1	1	1	1	3	1	1	1	2	1
6901	2	5	2	1	2	1	2	2	1	1	2	1	1	1	1	2	3	2	1	1	1	1	1
6925	2	5	2	1	2	1	3	2	3	1	2	1	1	2	1	1	2	1	1	1	1	1	1
6860	2	5	3	1	1	1	2	2	2	1	3	2	1	2	1	3	2	3	2	1	1	3	3
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6922	2	5	2	3	3	1	1	3	1	1	3	1	2	1	2	3	1	3	2	1	1	1	2
6898	2	5	2	2	2	1	3	3	1	2	1	2	2	2	1	1	1	1	1	1	1	1	1
5894	1	6	3	1	2	1	3	2	1	1	1	1	2	2	3	3	1	2	1	1	1	1	1
6713	1	5	2	2	2	1	2	2	1	1	1	1	1	2	2	3	1	1	1	2	1	1	2
6883	2	5	2	2	2	1	3	2	2	1	3	1	1	3	3	2	3	3	1	1	1	1	1
6895	1	5	2	2	1	1	2	2	3	1	1	1	2	2	2	2	2	2	2	1	1	2	1
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6791	2	5	3	2	2	1	3	2	2	3	1	2	1	3	1	3	1	2	1	2	1	1	3
6711	2	5	1	1	1	1	2	2	1	1	1	1	2	1	3	3	3	2	3	1	1	2	1
6887	2	5	2	2	3	1	3	3	1	1	3	1	2	2	2	3	1	2	1	2	1	1	1
6686	2	5	1	2	2	1	3	3	1	1	2	1	2	2	3	1	1	1	1	1	1	1	1
6926	2	5	2	2	3	2	2	3	1	1	2	1	2	2	2	3	3	2	2	1	1	2	1
6851	2	5	3	2	2	2	3	2	2	2	1	1	2	2	2	3	2	2	1	1	1	1	2
6907	2	5	2	1	2	1	3	2	1	1	1	1	1	2	1	3	3	3	1	3	1	1	1
6892	1	5	2	2	2	1	3	3	1	1	3	1	2	1	2	3	2	3	1	3	1	1	1
6662	1	5	1	2	2	1	3	2	2	1	2	1	1	2	1	2	2	2	1	1	1	1	1
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6875	2	5	2	1	1	1	2	2	3	1	1	1	1	2	2	2	2	2	1	2	2	1	2
6694	2	5	1	2	1	1	2	2	1	1	1	1	2	3	2	2	3	1	1	1	1	1	1
6670	2	5	1	1	2	1	3	2	2	1	1	1	1	2	2	3	1	1	1	1	2	1	1
6718	2	5	1	1	2	1	3	2	3	2	1	1	2	2	1	1	2	2	1	1	2	1	1
6813	2	5	3	2	2	1	3	1	3	2	1	2	1	3	1	2	2	1	1	2	2	1	2
6897	2	5	2	2	2	1	3	2	1	1	1	1	2	2	1	2	2	2	1	2	2	2	1
6885	2	5	2	2	2	1	2	2	1	1	2	2	2	1	1	2	2	2	1	1	1	1	1
6721	1	5	2	2	2	1	2	3	2	2	3	2	3	2	2	3	2	3	1	1	1	1	2
6893	1	5	2	1	1	1	2	2	2	1	1	1	2	2	2	1	1	2	1	3	2	1	1
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6918	2	5	2	1	2	1	2	2	3	3	2	1	1	2	3	3	3	2	2	3	2	1	2
6908	2	5	2	2	2	1	3	1	1	1	2	1	2	2	1	2	2	2	2	3	1	1	1
6903	2	5	2	2	2	1	3	3	2	1	2	1	2	2	2	3	2	1	1	3	2	1	1
6924	2	5	2	2	2	2	3	2	2	1	1	2	2	2	1	2	1	1	3	3	2	1	1
6678	2	5	1	1	2	1	2	1	1	1	1	1	1	2	2	2	3	3	1	1	3	1	1
6910	2	5	2	1	2	1	3	3	2	1	3	1	1	3	1	1	1	2	1	1	3	1	1
6698	2	5	1	1	2	1	2	2	2	2	1	1	2	3	1	2	2	2	1	1	3	3	1
6684	2	5	1	3	3	2	1	2	1	1	2	1	1	1	3	2	1	2	1	1	3	2	1
6679	2	5	1	2	2	1	3	2	1	1	2	1	1	1	2	2	1	2	1	1	3	2	2
6712	1	5	1	2	2	1	2	3	1	1	2	1	1	1	3	2	1	2	1	1	3	3	1
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6702	2	5	1	2	2	1	3	3	2	1	3	1	2	1	1	1	1	3	1	1	3	1	1
6697	2	5	1	2	3	1	3	2	2	1	3	1	2	2	1	3	2	2	1	1	3	1	1
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6680	2	5	1	2	3	1	2	3	2	1	2	2	2	1	2	2	1	2	1	1	3	2	2
6692	2	5	1	1	2	1	2	3	1	1	1	1	2	1	1	1	1	1	2	2	3	1	1
6722	2	5	1	1	2	1	3	2	1	1	3	1	2	2	1	1	1	1	1	1	3	1	1
6899	2	5	2	2	2	1	3	2	1	1	1	1	1	2	1	1	1	2	1	2	3	1	1
6693	2	5	1	2	2	1	3	2	2	1	1	1	1	2	1	3	3	3	1	2	3	1	1
6708	2	5	1	1	1	1	2	2	3	1	1	1	2	3	1	1	2	2	1	1	3	1	1
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6688	2	5	1	1	2	1	3	2	3	2	1	1	1	1	1	1	1	1	2	2	3	1	1
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6923	2	5	2	2	2	2	3	2	2	2	3	1	1	2	2	2	2	2	1	1	3	1	1
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6669	2	5	1	2	3	1	3	3	1	1	1	1	2	1	3	2	2	2	1	1	3	3	3
6723	2	5	1	2	3	1	2	3	2	1	1	1	2	2	2	2	2	2	1	2	3	1	1
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6719	2	5	1	2	3	1	2	3	2	2	3	2	2	3	2	3	2	3	1	1	3	2	1
6671	2	5	1	2	3	2	2	3	1	1	2	1	3	1	2	2	2	2	1	1	3	2	1
6675	2	5	1	2	2	1	3	2	2	1	1	1	1	2	2	3	3	2	2	3	3	2	1
6438	2	5	3	2	1	1	3	2	3	1	1	1	1	2	3	2	1	2	1	3	3	1	1
6704	2	5	1	2	2	1	3	2	2	2	1	1	1	2	1	2	2	2	1	3	3	1	1
6672	2	5	1	2	2	2	3	1	2	1	1	2	1	2	2	1	2	3	1	3	3	1	1
6878	2	5	2	1	2	1	3	2	2	1	1	1	2	1	2	3	2	3	1	3	3	1	1
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6927	2	5	2	2	3	1	3	3	1	1	3	1	2	2	2	1	2	2	1	3	3	1	1
6705	2	5	1	2	2	1	2	2	2	2	2	1	1	2	1	2	2	2	1	2	3	1	2
5872	1	6	3	1	3	1	3	3	1	1	2	3	3	1	2	3	1	3	2	1	2	2	2
6933	2	5	1	3	3	1	1	3	1	1	2	2	3	1	2	2	1	2	1	1	1	1	1
6673	2	5	1	2	2	2	3	2	2	1	3	1	2	2	1	3	2	3	1	3	1	3	2
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6685	2	5	1	2	3	2	1	2	1	2	2	1	2	2	2	3	3	3	1	1	3	1	1
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6737	2	5	3	1	2	2	3	1	1	1	1	1	2	2	1	1	1	1	1	1	2	1	1
6888	2	5	2	2	1	1	2	2	2	1	2	2	1	2	1	2	1	1	1	1	1	1	1
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6699	2	5	1	2	2	1	3	2	2	1	1	1	2	2	2	2	1	3	1	1	3	1	1
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10853	2	2	1	2	3	1	2	2	1	1	3	1	2	1	3	2	2	2	1	2	1	3	2
13094	2	1	1	1	2	1	3	3	2	1	2	2	2	2	2	2	1	2	1	2	1	2	1
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13162	2	1	1	1	2	2	3	3	1	1	2	2	1	2	3	3	2	2	1	2	2	1	2
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11833	1	2	1	1	1	1	3	2	1	1	1	1	2	2	2	3	3	2	1	3	2	1	2
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10842	2	2	1	1	1	2	2	2	2	1	3	1	1	3	1	1	1	2	1	1	1	1	1
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13166	2	1	1	2	1	1	3	3	3	2	2	1	1	1	3	2	1	2	1	1	1	1	1
13093	2	1	1	1	1	1	3	1	1	1	2	2	2	1	2	3	2	3	2	3	1	1	3
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10729	2	2	1	1	1	2	2	1	2	1	1	3	3	2	3	3	1	3	1	1	1	1	3
11843	1	2	1	1	2	1	3	2	1	2	1	2	2	2	3	2	2	2	2	2	2	2	2
11872	2	2	1	2	2	1	3	2	2	2	1	1	2	3	1	2	3	3	2	3	1	1	2
10854	2	2	1	1	1	2	3	2	2	1	2	1	1	3	1	1	1	3	1	1	1	1	1
11894	2	2	1	1	1	1	3	2	2	1	3	1	1	2	1	2	2	2	1	1	1	1	1
11898	2	2	1	1	1	1	3	1	2	1	1	1	1	2	1	2	2	2	1	1	1	1	1
10752	2	2	1	1	2	1	3	1	2	1	2	1	1	2	3	1	1	3	1	1	1	2	2
11891	1	2	1	1	1	1	2	2	1	1	3	1	1	3	1	1	2	3	3	1	1	3	2
13105	1	1	1	1	1	1	3	2	1	1	3	2	1	3	3	1	1	2	1	1	1	1	2

13090	2	1	1	1	2	1	3	2	3	2	1	1	2	2	2	1	2	3	1	1	1	3	1
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M	G	S	P	EM	SM	HF	o1	o2	o3	o4	o5	o6	o7	o8	o9	ot
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6903	2	5	2.	2.	3	1	2	2	1	2	3	3	1	2
6924	2	5	2.	3.	1	1	1	2	2	1	1	3	1	2
6678	2	5	1.	4.	3	1	2	2	1	1	1	3	1	1
6910	2	5	2.	0.	2	1	3	3	1	1	1	3	1	1
6698	2	5	1.	1.	1	1	1	2	1	1	1	3	1	1
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6712	1	5	1.	2.	3	1	2	3	1	2	1	3	1	2
6656	2	5	1.	2.	2	1	1	3	1	1	2	3	1	2
6702	2	5	1.	4.	2	1	1	3	1	1	1	3	1	1
6697	2	5	1.	5.	3	1	3	3	3	2	1	3	1	2
6696	2	5	1.	5.	2	1	1	2	1	1	1	3	1	1
6628	2	5	1.	2.	2	1	3	3	1	1	2	3	1	1
6677	2	5	1.	4.	3	1	2	3	1	1	1	3	1	1
6695	2	5	1.	1.	3	1	3	3	1	1	2	3	1	2
6681	2	5	1.	2.	3	1	3	2	1	1	1	3	1	1
6680	2	5	1.	0.	3	1	3	3	2	2	2	3	1	1
6692	2	5	1.	3.	2	1	3	3	1	1	1	3	1	2
6722	2	5	1.	3.	2	1	1	3	1	1	1	3	1	2
6899	2	5	2.	2.	3	1	3	3	2	1	1	3	1	2
6693	2	5	1.	5.	3	1	3	3	1	1	2	3	1	1
6708	2	5	1.	3.	3	1	3	3	1	1	1	3	1	1
6818	2	5	3.	2.	1	1	1	3	1	1	1	3	1	1
6688	2	5	1.	3.	2	1	3	3	2	1	1	3	1	1
6889	1	5	2.	1.	3	1	1	3	1	1	2	3	1	1
6923	2	5	2.	1.	1	1	3	3	1	2	3	3	1	1
6886	2	5	2.	2.	2	1	3	3	1	3	2	3	1	1
6716	2	5	1.	2.	1	1	1	3	1	1	2	3	1	2
6669	2	5	1.	4.	3	1	2	3	3	1	1	3	1	1
6723	2	5	1.	1.	2	1	2	3	1	2	1	3	1	3
6906	2	5	2.	2.	3	1	3	3	1	2	2	3	1	1
6719	2	5	1.	1.	2	1	3	3	1	1	2	3	1	2
6671	2	5	1.	3.	1	1	2	2	1	1	2	3	1	2
6675	2	5	1.	4.	2	1	3	2	1	1	2	3	1	2
6438	2	5	3.	1.	3	1	3	3	1	1	3	3	1	1
6704	2	5	1.	3.	3	1	3	3	1	2	1	3	1	1
6672	2	5	1.	4.	1	1	2	3	2	2	2	3	1	1
6878	2	5	2.	3.	3	1	3	1	1	1	1	3	1	1
6674	2	5	1.	2.	3	1	3	1	2	2	1	3	1	1
6927	2	5	2.	0.	2	1	2	3	1	2	1	3	1	1
6705	2	5	1.	3.	2	2	3	3	2	1	2	3	1	2
5872	1	6	3.	0.	2	1	1	3	3	2	1	1	2	3
6933	2	5	1.	2.	2	1	1	3	1	1	1	1	2	2
6673	2	5	1.	3.	3	1	3	3	1	1	1	2	2	1
6701	2	5	1.	2.	2	1	3	2	2	1	1	2	2	2
6685	2	5	1.	1.	2	1	1	2	1	2	2	2	2	1
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6737	2	5	3.		0.		2	1	2	1	1	1	2	3	2	1
6888	2	5	2.		5.		3	1	1	2	2	2	1	3	2	1
6690	2	5	1.		4.		2	1	3	3	1	1	2	3	2	3
6699	2	5	1.		4.		3	1	3	2	1	1	2	3	2	1
6687	2	5	1.		4.		2	1	3	3	1	1	2	3	2	1
6691	2	5	1.		3.		3	1	3	3	1	2	2	3	2	1
6709	2	5	1.		1.		3	1	3	3	2	1	2	3	2	2
6911	2	5	2.		0.		2	1	3	3	1	1	2	3	2	2
6750	2	5	3.		1.		1	2	3	3	3	1	2	2	3	3
4596	2	6	1.		2.		3	2	3	3	1	2	3	2	3	1
13161	2	1	1	70	2	1	2	1	2	3	1	3	3	2	1	1
11883	1	2	1	49	2	2	3	2	1	3	1	1	2	3	1	1
13148	2	1	1	62	4	2	3	2	2	3	2	1	1	3	3	3
13144	2	1	1	67	3	3	1	1	3	3	1	2	1	3	1	1
13115	1	1	1	48	2	3	2	2	3	3	2	2	2	3	1	3
13847	1	1	1	59	2	3	3	1	3	3	1	1	1	3	1	2
10651	2	2	1	81	2	3	3	1	3	3	1	1	2	3	1	2
10853	2	2	1	58	2	3	3	1	2	3	2	1	1	3	2	2
13094	2	1	1	66	2	3	3	2	3	3	2	2	2	3	2	2
13168	2	1	1	79	4	3	1	1	2	3	1	1	1	3	2	1
13170	1	1	1	65	1	4	1	2	2	3	1	1	1	3	1	1
13113	1	1	1	71	2	4	2	1	3	3	1	2	3	2	1	1
13162	2	1	1	77	1	4	1	1	3	3	1	2	2	3	1	1
11931	2	2	1	91	1	9	3	2	3	3	1	1	2	3	1	1
12890	2	2	1	81	2	2	3	2	3	3	2	2	1	3	1	2
11833	1	2	1	30	0	5	2	1	2	3	1	1	1	2	1	1
11838	2	2	1	66	3	5	2	2	3	3	1	1	1	2	1	2
10831	2	2	1	71	4	5	1	2	2	3	2	1	1	3	1	2
13878	2	1	1	62	4	5	3	2	3	3	1	1	1	3	1	1
10863	2	2	1	77	2	5	2	1	3	2	1	2	2	3	1	2
10842	2	2	1	61	4	5	3	1	3	1	1	2	2	3	1	1
10773	2	2	1	42	3	5	3	1	2	1	1	1	1	3	1	1
13863	2	1	1	84	3	5	3	1	3	3	1	1	1	3	1	1
13149	2	1	1	65	1	5	3	1	3	3	1	1	1	3	1	3
11871	2	2	1	74	2	5	3	3	3	3	1	1	1	3	1	1
13166	2	1	1	75	3	5	1	1	3	3	1	1	3	3	2	1
13093	2	1	1	75	3	5	3	2	3	3	3	2	3	3	2	3
12064	2	2	1	54	2	5	1	1	2	3	1	1	1	3	2	1
10867	2	2	1	87	1	9	2	1	3	3	1	1	1	3	2	1
10729	2	2	1	67	0	10	3	2	3	3	3	2	2	2	1	2
11843	1	2	1	74	1	11	2	1	2	2	2	1	2	2	2	2
11872	2	2	1	82	1	12	1	2	3	3	1	1	2	3	1	1
10854	2	2	1	47	3	6	3	1	3	3	2	1	1	2	1	1
11894	2	2	1	55	2	6	2	2	3	3	1	1	2	2	2	1
11898	2	2	1	63	3	6	3	2	3	3	1	1	2	2	1	1
10752	2	2	1	67	2	6	3	1	3	3	1	1	2	3	2	2
11891	1	2	1	63	7	6	3	1	3	3	1	1	1	3	1	2
13105	1	1	1	65	2	6	1	2	1	1	1	1	1	2	1	2

13090	2	1	1	68	3	6	3	2	2	3	1	2	1	2	1	1
11842	2	2	1	63	1	6	1	1	3	3	3	2	2	3	1	1
10843	2	2	1	54	0	6	2	2	2	3	1	1	2	3	1	2
11923	2	2	1	56	1	6	1	1	2	2	1	1	1	2	1	1
10835	2	2	1	87	2	6	2	2	1	3	1	2	1	3	1	2
13158	2	1	1	69	1	6	1	1	2	3	1	1	2	3	1	1
13179	2	1	1	85	1	6	2	2	3	3	3	1	3	3	1	1
11858	2	2	1	59	0	6	2	1	3	3	2	2	2	3	1	2
11867	2	2	1	62	0	6	3	2	3	1	1	1	2	3	1	2
13145	2	1	1	71	4	6	3	1	2	3	1	1	2	3	1	3
12885	2	2	1	68	3	6	1	1	3	3	2	1	2	3	1	1
13112	1	1	1	41	2	6	2	1	2	3	1	1	1	3	1	1
11873	2	2	1	47	1	6	3	1	2	3	1	2	2	3	1	3
13165	2	1	1	73	5	6	3	1	3	3	1	1	2	3	1	3
11836	2	2	1	59	3	6	1	1	3	3	1	2	2	3	1	2
13084	1	1	1	76	4	6	3	1	3	3	1	1	1	3	1	1
13173	2	1	1	74	5	6	2	1	3	3	3	2	2	2	2	2
10856	2	2	1	53	5	6	1	1	3	3	2	1	2	3	2	3
13154	2	1	1	32	4	6	1	1	3	3	1	2	2	3	2	2
11916	2	2	1	78	2	9	2	1	3	3	1	1	1	3	2	3
10838	2	2	1	75	2	9	1	1	1	3	1	2	2	2	2	2
11927	2	2	1	68	1	10	3	1	3	3	1	3	3	1	2	2
12894	1	2	1	87	1	12	2	2	3	3	1	2	2	3	1	2
10742	2	2	1	62	1	16	3	1	3	3	2	1	3	3	1	1
13104	2	1	1	67	0	7	1	2	2	3	1	2	2	2	2	1
13100	1	1	1	78	2	7	2	1	3	2	1	1	1	3	1	3
11896	2	2	1	72	3	7	3	1	2	3	2	1	1	3	1	2
10833	2	2	1	73	2	7	3	1	3	3	1	1	1	2	1	1
10650	1	2	1	24	2	7	1	2	3	1	3	1	2	3	1	3
13116	1	1	1	29	2	7	1	1	3	3	2	2	1	3	1	1
11874	2	2	1	68	1	7	2	1	3	3	1	1	1	3	1	3
11932	1	2	1	77	4	7	3	1	3	3	1	1	1	3	1	1
10828	2	2	1	71	5	7	2	1	1	3	1	1	1	3	1	2
10826	2	2	1	60	3	7	2	1	3	3	2	1	2	3	1	1
10636	2	2	1	54	0	7	1	1	3	3	1	2	1	3	1	1
13155	2	1	1	66	1	7	1	1	3	3	2	2	1	3	1	3
13153	2	1	1	80	4	7	3	1	3	3	1	1	2	3	2	2
11897	2	2	1	84	3	7	3	2	2	3	2	1	3	3	2	2
13096	1	1	1	60	4	7	3	1	3	3	1	2	1	3	2	2
11824	2	2	1	42	1	9	3	2	2	3	2	1	1	3	2	1
12898	2	2	1	70	1	10	1	1	3	2	1	1	2	3	1	1
10869	2	2	1	83	2	11	3	1	2	2	1	2	1	2	2	1
11910	2	2	1	65	1	11	3	1	3	3	1	1	1	3	2	1
11937	2	2	1	58	0	12	2	2	3	3	1	1	2	3	1	3
10860	2	2	1	63	5	4	3	1	3	3	1	1	1	3	1	1
11922	2	2	1	84	3	8	3	2	3	3	2	1	2	2	1	2
11936	2	2	1	91	1	8	1	2	1	3	1	1	1	2	1	2
10862	2	2	1	66	2	8	1	2	3	3	3	2	3	2	1	2
12899	2	2	1	68	3	8	1	1	3	3	1	2	2	2	1	2
12893	2	2	1	78	4	8	3	1	3	3	1	2	2	3	1	2

10844	2	2	1	51	3	8	3	2	3	3	2	3	3	3	1	1
10832	2	2	1	40	3	8	1	1	3	3	2	2	3	3	1	2
12895	1	2	1	60	2	8	1	1	3	2	2	1	1	3	1	2
11878	1	2	1	51	2	8	1	1	2	2	2	1	2	3	1	1
13111	1	1	1	43	3	8	3	1	2	3	2	2	2	3	1	1
13178	1	1	1	64	3	8	3	1	3	3	2	2	1	3	1	2
13083	1	1	1	39	1	8	2	1	3	3	2	1	1	3	1	2
13114	1	1	1	76	2	8	3	1	3	3	2	1	1	3	1	1
10841	2	2	1	78	2	8	1	1	3	3	1	2	2	3	1	1
11848	2	2	1	55	1	8	2	1	3	3	2	2	2	3	2	1
11924	2	2	1	47	1	8	3	1	3	2	3	2	3	3	2	2
10861	2	2	1	57	1	10	3	1	3	2	2	1	1	3	1	2
10866	2	2	1	72	2	10	3	1	3	3	2	2	3	3	2	1
11934	2	2	1	71	2	12	1	2	1	3	2	1	1	2	2	2
10834	2	2	1	78	3	12	3	2	3	3	1	1	2	2	1	3
13092	1	1	1	82	1	13	3	1	2	3	1	1	2	3	1	1
13018	1	1	1	84	1	15	3	1	3	3	2	2	1	3	1	2
11835	2	2	1	57	1	16	3	1	3	1	2	1	2	3	1	1
13099	2	1	1	61	1	17	1	1	3	3	1	1	1	2	1	1
11918	2	2	1	72	2	9	3	2	1	3	2	1	1	2	1	1
10751	2	2	1	66	1	9	2	2	2	3	2	3	2	3	1	1
11930	2	2	1	42	3	9	3	2	3	3	1	1	1	2	1	1
11914	2	2	1	80	2	9	3	2	3	3	1	1	1	3	1	3
10738	2	2	1	86	3	9	3	2	3	3	1	1	2	3	1	2
11868	2	2	1	71	2	9	3	2	3	3	1	1	1	3	1	1
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13097	1	1	1	52	1	9	1	1	3	3	1	2	2	3	1	2
13147	1	1	1	46	3	9	3	1	3	3	1	1	2	3	1	2
13176	2	1	1	72	5	9	2	1	3	3	3	3	2	3	3	3
11902	2	2	1	73	2	13	1	1	1	3	2	1	1	2	1	2
11853	2	2	1	82	0	15	3	1	3	3	2	2	2	3	1	2
13171	1	1	1	57	4	5	3	1	2	3	3	2	1	3	1	1
10625	1	2	1	38	5	5	1	3	1	1	1	2	1	1	2	1
13085	2	1	1	81	4	6	3	1	3	3	1	2	2	3	1	3
13117	1	1	1	37	1	10	3	2	3	1	1	3	2	1	2	1
10836	2	2	1	58	5	10	2	1	2	3	1	1	1	2	1	1
10829	2	2	1	80	2	10	3	1	3	3	1	1	3	3	1	2
13146	2	1	1	81	1	10	3	1	3	2	3	1	3	2	1	1
11864	1	2	1	73	4	10	3	1	3	3	1	2	1	3	1	2
11875	1	2	1	76	3	10	3	1	3	3	2	1	2	2	2	2
11870	2	2	1	47	4	10	2	2	2	2	2	1	1	2	2	2
10737	2	2	1	82	3	11	3	1	2	3	1	1	1	2	2	1
10629	2	2	1	61	4	11	3	2	3	3	2	2	2	2	2	1
10846	2	2	1	42	4	11	3	2	2	3	1	1	3	2	1	1
10624	1	2	1	41	2	11	1	2	3	3	1	1	1	2	1	1
11846	2	2	1	48	3	11	1	2	3	2	1	1	1	3	1	2
11900	2	2	1	66	4	11	3	2	3	3	1	3	2	3	1	1
13087	2	1	1	71	2	11	1	3	1	3	3	1	1	3	1	1
10837	2	2	1	56	4	11	3	1	3	3	1	2	3	3	3	1
10849	2	2	1	60	3	16	2	1	1	3	1	3	2	2	2	2

10865	2	2	1	80	3	19	3	1	3	3	1	3	2	2	2	1
11856	2	2	1	68	5	8	3	1	3	3	1	1	1	3	1	2
10851	2	2	1	62	5	10	3	1	3	3	1	1	1	3	2	1
12888	2	2	1	64	2	12	1	1	3	3	1	1	1	1	1	3
10827	1	2	1	51	2	12	3	1	1	2	1	1	2	1	2	1
11890	1	2	1	67	3	12	3	2	3	3	3	1	2	2	1	3
11912	2	2	1	59	2	12	1	1	2	2	1	1	2	3	1	1
11865	2	2	1	70	3	12	2	2	2	3	1	1	1	3	1	1
13110	1	1	1	64	2	12	3	2	3	3	1	3	1	3	1	1
10871	2	2	1	78	3	12	3	1	3	3	2	1	3	3	1	2
10802	2	2	1	73	3	12	3	1	3	3	1	2	1	3	1	1
11913	2	2	1	75	4	13	3	1	3	2	1	1	1	2	1	1
11909	2	2	1	67	3	13	3	2	3	2	1	1	2	3	1	1
13177	1	1	1	65	2	13	3	1	3	3	1	2	1	3	1	1
11863	2	2	1	47	3	13	3	1	3	2	1	2	2	3	1	2
13098	2	1	1	75	4	13	3	1	3	3	1	2	2	3	1	2
12897	1	2	1	82	4	13	1	1	3	3	1	1	1	3	2	1
11908	2	2	1	62	2	13	3	1	3	3	1	2	2	3	2	1
10855	2	2	1	63	3	14	3	1	3	3	1	2	2	2	2	1
13893	1	1	1	68	2	14	2	2	1	2	1	1	3	2	1	1
13088	2	1	1	78	2	14	3	1	3	3	1	2	2	3	1	2
11887	1	2	1	79	4	14	3	2	3	3	1	1	1	3	1	1
13086	1	1	1	61	3	15	3	2	3	3	1	1	2	2	2	1
13102	1	1	1	50	3	15	3	1	3	3	1	1	3	3	1	1
13091	1	1	1	68	4	17	2	1	3	3	1	1	1	3	1	1
11876	2	2	1	66	4	19	3	1	3	3	1	1	1	3	1	1

Appendix AA

Raw data from the third stage study

M	G	P	S	HF	DS	MC	o1	o2	o3	o4	o5	q1	q2	q3	q4	q5	q6	q7	q8	q9	qt	qe	qw	qr	qf	qn
6774	2	3	2	2	7	18	0	0	0	0	0	3	2	1	3	1	2	1	4	3	3	3	3	2	3	2
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7319	1	1	4	9	5	19	3	3	3	2	3	1	3	2	3	2	3	4	4	2	3	3	3	2	2	1
12488	1	1	5	9	5	30	2	4	4	3	3	3	2	1	3	2	2	4	4	3	3	4	2	2	1	2
12500	2	1	5	9	5	18	3	3	3	3	3	3	2	2	3	2	2	4	4	1	4	4	4	2	1	3
12510	2	1	5	9	5	11	3	3	3	3	3	2	3	1	3	3	3	4	4	1	2	2	4	4	4	4
9555	2	2	1	9	5	13	0	0	0	0	0	3	3	2	3	3	3	4	4	4	3	4	1	2	4	4
9557	2	2	1	9	5	20	0	0	0	0	0	1	2	2	3	1	2	4	4	3	3	4	2	2	4	2
8557	2	2	3	9	5	11	3	3	2	3	2	2	3	2	3	1	2	4	4	1	3	4	3	4	1	4

11832	2	1	2	9	5	2	0	0	0	0	0	1	3	3	1	3	2	1	4	2	2	1	2	4	4	4
14973	1	1	2	9	6	22	0	0	0	0	0	3	2	1	1	2	2	4	4	4	4	2	2	4	3	3
7655	2	1	3	9	6	18	2	4	4	2	2	3	2	2	3	2	2	4	4	1	3	3	2	3	3	2
7356	2	1	4	9	6	12	5	2	3	2	3	1	2	2	1	2	1	1	1	3	2	1	1	2	2	3
12459	2	1	5	9	6	24	2	3	4	1	1	3	2	1	3	2	2	4	4	1	3	2	1	2	1	2
12465	2	1	5	9	6	16	2	4	1	2	4	1	3	1	1	3	2	4	4	4	3	1	4	4	1	4
6763	2	3	2	9	6	18	0	0	0	0	0	3	3	1	3	2	3	4	4	4	3	2	2	4	1	2
6810	2	3	2	9	6	25	0	0	0	0	0	3	2	1	3	2	2	4	4	2	3	3	4	2	4	4
7345	2	1	4	9	7	10	5	1	5	5	1	1	1	1	3	3	1	4	3	1	3	2	3	2	2	2
12464	2	1	5	9	7	26	2	3	4	2	2	3	2	1	3	2	2	4	4	3	1	4	4	4	2	2
6803	2	3	2	9	7	20	0	0	0	0	0	3	3	1	3	2	2	4	4	1	3	2	2	2	3	3
7355	2	1	4	9	8	32	3	3	3	3	2	3	2	1	3	2	2	4	4	3	3	4	2	4	2	2
12491	2	1	5	9	8	24	1	2	3	3	3	3	3	1	1	1	2	4	4	2	3	4	2	1	2	3
12494	2	1	5	9	8	24	2	2	2	2	2	3	3	1	1	1	2	4	4	3	3	4	2	4	2	1
12495	2	1	5	9	8	15	3	3	2	1	4	3	2	2	1	2	2	4	4	2	3	3	2	4	2	4
12112	2	2	1	9	8	19	0	0	0	0	0	2	2	1	3	2	2	3	4	3	3	4	3	4	1	3
10852	1	1	1	9	9	9	0	0	0	0	0	2	3	1	2	3	1	4	2	4	2	3	3	2	1	4
12478	2	1	5	9	9	11	5	2	4	2	3	2	2	2	1	2	3	4	4	3	4	4	3	1	3	1
7321	1	1	4	10	5	7	3	3	4	2	2	1	3	1	1	1	1	4	1	1	1	2	3	4	4	4
11228	2	2	1	10	5	27	0	0	0	0	0	3	2	1	3	3	2	4	4	3	3	4	3	3	3	4
6746	2	3	2	10	5	10	0	0	0	0	0	1	3	1	3	3	2	4	4	2	3	4	2	1	3	1
12132	2	2	1	10	5	12	0	0	0	0	0	3	3	2	3	3	1	4	2	3	2	4	1	1	1	3
10681	1	1	1	10	6	20	0	0	0	0	0	3	2	2	1	2	2	4	4	3	3	3	3	3	1	1
11892	1	1	1	10	6	31	0	0	0	0	0	3	2	1	3	2	2	4	4	1	3	2	3	3	1	3
7316	1	1	4	10	6	17	3	2	3	3	3	3	2	1	3	3	2	4	2	1	4	1	2	3	3	2
12439	1	1	5	10	6	19	2	4	3	2	2	1	2	2	3	2	2	4	4	2	3	3	1	2	1	2
12499	2	1	5	10	6	21	2	2	3	2	2	3	3	2	3	3	2	4	4	3	3	3	4	3	3	3
12501	2	1	5	10	6	13	5	3	3	3	5	3	2	3	1	2	1	4	1	3	2	4	3	2	4	3
12127	2	2	1	10	6	19	0	0	0	0	0	3	2	2	3	3	1	4	4	3	1	1	3	1	4	3
6487	2	2	2	10	6	21	0	0	0	0	0	3	2	1	3	2	2	4	4	1	4	4	2	1	1	3
10680	2	1	1	10	7	21	0	0	0	0	0	3	3	1	1	2	2	4	4	4	4	2	2	3	3	2
7342	2	1	4	10	7	21	4	2	5	1	4	3	3	2	1	3	2	4	4	3	3	4	2	3	2	3
12442	2	1	5	10	7	22	2	2	2	2	2	3	3	2	1	1	2	4	4	3	3	4	2	2	2	1
9564	2	2	1	10	7	21	0	0	0	0	0	1	3	1	2	2	2	4	4	4	3	2	2	4	3	4
9015	1	2	3	10	7	22	2	1	3	5	3	3	2	1	1	2	1	4	4	3	1	3	1	4	4	3
7659	1	1	3	10	8	29	1	3	3	2	1	3	2	1	3	2	1	4	4	3	1	3	1	4	2	3
12481	2	1	5	10	8	19	3	2	4	2	1	2	3	2	3	2	2	4	4	2	3	1	1	1	1	3
12504	2	1	5	10	9	22	2	2	4	4	3	2	2	2	3	2	2	4	4	1	3	1	3	1	1	3
12446	2	1	5	11	4	25	2	3	4	2	3	3	2	2	3	2	2	4	4	1	3	1	4	2	3	2
12458	1	1	5	11	4	19	2	4	3	3	2	3	3	2	3	2	2	4	4	2	2	1	3	2	3	3
12483	2	1	5	11	4	16	3	3	3	3	3	3	3	3	3	3	2	4	4	2	1	1	4	2	1	3
12511	2	1	5	11	4	21	2	3	3	2	2	3	3	1	3	3	3	4	4	2	3	1	3	3	2	3
11852	1	1	1	11	5	14	0	0	0	0	0	3	2	2	3	1	3	4	4	1	4	4	2	4	1	1
12470	1	1	5	11	5	16	2	3	3	3	2	3	3	1	1	3	2	4	2	3	3	3	2	3	4	3
12513	1	1	5	11	5	25	3	2	3	3	3	3	2	2	3	2	2	4	4	4	3	4	1	4	2	2
8541	2	2	3	11	5	13	3	3	4	4	3	3	2	1	3	2	2	4	4	4	3	3	3	2	4	4
7350	2	1	4	11	5	9	3	4	2	2	3	3	3	2	1	2	2	4	1	2	2	4	4	4	4	4
12925	2	2	1	11	5	11	0	0	0	0	0	1	2	1	3	2	1	4	4	2	1	1	3	1	4	3
10676	1	1	1	11	6	16	0	0	0	0	0	1	2	1	1	2	2	1	2	3	3	2	3	2	3	2
7353	1	1	3	11	6	16	2	4	3	2	3	3	3	2	3	2	3	4	4	1	1	3	2	4	3	3

11872	2	1	5	11	6	14	3	4	3	1	4	2	2	2	3	2	2	4	4	1	2	2	1	4	3	4
11889	1	1	5	11	6	22	2	4	2	2	3	3	2	1	3	2	3	4	4	1	3	2	2	2	1	4
12429	1	1	5	11	6	14	3	2	3	2	1	1	2	2	3	3	2	4	4	2	3	4	2	4	3	4
12450	1	1	5	11	6	16	3	3	3	3	3	3	2	2	2	1	2	4	4	1	4	4	3	4	1	3
12463	2	1	5	11	6	16	3	4	3	2	1	2	3	1	3	2	1	4	4	1	1	4	3	2	2	2
12468	2	1	5	11	6	18	2	3	4	2	3	3	2	2	3	1	1	4	4	1	3	4	4	2	3	2
12486	1	1	5	11	6	14	5	1	5	1	3	3	2	2	2	3	2	4	4	3	2	4	2	1	2	2
12073	1	2	1	11	6	23	0	0	0	0	0	1	2	1	3	2	2	4	4	3	3	4	3	4	2	2
12102	2	2	1	11	6	29	0	0	0	0	0	2	2	1	3	2	2	4	4	2	3	2	2	4	4	3
8877	2	2	3	11	6	18	2	3	3	1	2	3	3	1	3	2	1	4	4	2	3	4	1	2	1	3
7320	2	1	4	11	7	21	2	2	3	3	3	2	2	1	1	2	2	4	4	3	3	4	3	3	1	1
6734	2	3	2	11	7	23	0	0	0	0	0	1	2	1	3	2	2	4	4	1	2	4	2	2	1	1
12453	2	1	5	11	8	19	3	3	5	3	3	3	3	2	3	3	2	4	4	1	3	4	1	4	2	2
12509	2	1	5	11	8	25	3	3	3	3	3	3	3	1	3	3	2	4	4	4	3	4	4	4	1	1
6764	2	3	2	11	8	23	0	0	0	0	0	3	3	1	3	3	2	4	4	4	3	2	2	2	1	1
6317	2	3	2	11	9	16	0	0	0	0	0	3	3	2	1	3	3	3	4	3	3	3	4	2	3	2
6787	2	3	2	12	4	15	0	0	0	0	0	2	3	1	3	1	2	4	4	4	3	3	4	3	3	1
7312	2	1	4	12	5	34	1	2	2	2	2	3	2	1	3	2	2	4	4	3	1	2	3	3	2	2
12452	2	1	5	12	5	16	4	2	1	4	4	3	2	1	3	3	3	4	4	1	4	4	3	2	2	1
12460	2	1	5	12	5	10	2	3	4	2	3	3	3	2	3	3	2	4	4	2	3	1	2	4	1	2
10660	2	1	1	12	6	16	0	0	0	0	0	2	3	3	3	3	3	4	3	4	3	4	4	4	3	4
10732	2	1	1	12	6	13	0	0	0	0	0	2	2	2	3	3	2	4	2	3	3	4	4	2	4	4
7343	2	1	4	12	6	15	3	3	4	4	2	3	2	1	2	2	1	4	4	2	2	1	4	1	1	1
8518	2	2	3	12	6	16	4	4	4	3	4	1	2	1	3	2	1	4	4	2	1	3	4	2	4	2
7311	2	1	4	12	7	17	3	3	3	3	3	1	2	2	2	2	2	4	4	3	2	3	2	3	4	2
12512	2	1	5	12	7	18	2	4	3	2	2	3	2	3	3	2	1	4	4	4	2	4	3	4	3	4
8583	1	2	5	12	7	23	2	2	2	2	2	2	2	2	1	2	1	4	3	3	3	3	2	3	2	3
6747	2	3	2	12	7	25	0	0	0	0	0	3	2	2	3	3	3	4	4	3	3	2	3	2	1	3
6499	2	2	2	12	8	24	0	0	0	0	0	3	3	1	1	3	2	4	4	3	3	4	2	4	1	3
12444	2	1	5	13	3	14	3	4	3	2	2	3	2	2	3	2	3	4	1	1	2	4	4	4	2	1
10722	2	1	1	13	4	15	0	0	0	0	0	1	2	2	1	1	3	4	4	3	3	4	3	2	3	3
7309	2	1	4	13	5	24	5	2	5	1	5	3	2	1	3	2	1	4	4	2	4	3	4	1	2	4
12437	1	1	5	13	6	33	2	4	3	3	3	3	2	1	3	2	2	4	4	3	3	2	3	2	2	3
7344	2	1	4	13	7	17	3	4	3	3	2	3	3	2	3	3	2	4	4	1	3	2	3.	.		4
10721	2	1	1	13	8	18	0	0	0	0	0	3	3	1	1	1	2	4	4	1	4	4	2	2	2	3
7334	2	1	4	13	8	20	3	3	2	3	2	1	2	2	3	2	3	4	4	1	3	2	4	4	4	4
12498	1	1	5	13	9	15	5	1	5	5	5	2	3	3	3	3	2	4	4	1	2	1	2	2	2	1
12514	2	1	5	14	3	18	2	1	5	3	2	2	3	1	1	2	2	4	4	2	3	2	3	2	1	2
7306	1	1	4	14	5	10	3	3	3	4	4	2	3	1	3	3	2	4	3	1	4	1	1	3	1	1
6788	2	3	2	14	5	6	0	0	0	0	0	2	3	2	1	2	1	4	4	4	4	4	2	3	3	1
8808	2	1	3	14	6	15	3	2	3	3	2	3	3	2	3	2	2	4	4	2	2	4	4	2	1	2
7339	2	1	4	14	7	20	4	3	3	3	3	1	1	1	2	2	2	4	2	3	3	4	3	4	2	4
8514	2	2	3	14	7	21	3	3	4	4	3	3	2	1	3	2	2	4	4	4	3	3	3	2	4	4
9384	1	3	1	15	6	27	0	0	0	0	0	3	2	2	3	2	2	4	4	1	3	2	3	3	1	4
7348	2	1	4	15	8	17	4	3	3	3	3	1	3	2	1	2	2	4	2	1	3	4	2	4	2	4
7327	1	1	4	15	5	3	4	2	5	4	4	1	2	2	1	1	1	3	2	4	2	1	1	4	4	4
12433	2	1	5	16	6	22	5	1	5	2	4	3	2	1	3	2	2	4	4	4	3	4	4	2	1	4
7658	2	1	3	16	8	28	3	3	4	3	3	3	2	2	3	2	2	4	4	3	3	3	3	2	4	2
7654	2	1	3	17	5	18	3	4	3	2	2	3	3	1	1	2	1	4	4	3	4	1	2	3	3	3
12445	1	1	5	17	9	26	4	3	3	5	3	3	2	1	1	2	2	4	4	2	3	1	2	3	3	3

Appendix AB

Statistical Analyses

1.Exploratory study: Exam scores
Comparison between gender and between programmes of study (page 120)

Tests of Between-Subjects Effects

Dependent Variable: Exam scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1945.389(a)	3	648.463	3.000	.031
Intercept	626635.586	1	626635.586	2898.679	.000
SEX	923.912	1	923.912	4.274	.040
PROG	1175.563	1	1175.563	5.438	.020
SEX * PROG	342.464	1	342.464	1.584	.209
Error	62908.293	291	216.180		
Total	1074944.000	295			
Corrected Total	64853.681	294			

a R Squared = .030 (Adjusted R Squared = .020)

Multiple Regression analysis summary

Model	R	R-squared	Adjusted R-squared	S.E.
1	0.157 - a	0.025	0.018	14.718

A – Predictors (Constant), PROG, SEX

Coefficients

Model		B	S.E	Beta	t	Sig
1.	Constant	56.520	4.54	-	12.488	0.000
	SEX	3.867	2.068	0.106	1.841	0.067
	PROG	-3.464	1.766	-0.113	-1.961	0.051

2.Exploratory study: SCG scores
Comparison between gender and between programmes of study (page 128)

Tests of Between-Subjects Effects

Dependent Variable: SCG test scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	69.595(a)	3	23.198	2.188	.090
Intercept	50325.306	1	50325.306	4747.595	.000
SEX	1.630	1	1.630	.154	.695
PROG	27.059	1	27.059	2.553	.111
SEX * PROG	5.389	1	5.389	.508	.476
Error	3084.649	291	10.600		
Total	81461.090	295			
Corrected Total	3154.244	294			

a R Squared = .022 (Adjusted R Square

3.Exploratory study: DSBT scores
Comparison between gender and between programmes of study (page 129)

Tests of Between-Subjects Effects

Dependent Variable: HFT scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	48.338(a)	3	16.113	1.135	.335
Intercept	13814.033	1	13814.033	972.686	.000
SEX	19.085	1	19.085	1.344	.247
PROG	.268	1	.268	.019	.891
SEX * PROG	11.974	1	11.974	.843	.359
Error	4132.767	291	14.202		
Total	26362.000	295			
Corrected Total	4181.105	294			

a R Squared = .012 (Adjusted R Squared = .001)

4.Exploratory study: HFT scores
Comparison between gender and between programmes of study (page 132)

Tests of Between-Subjects Effects

Dependent Variable: DSBT scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	5.910(a)	3	1.970	1.156	.327
Intercept	9427.872	1	9427.872	5534.052	.000
SEX	.768	1	.768	.451	.503
PROG	.000	1	.000	.000	.991
SEX * PROG	2.924	1	2.924	1.716	.191
Error	495.751	291	1.704		
Total	15097.000	295			
Corrected Total	501.661	294			

a R Squared = .012 (Adjusted R Squared = .002)

5.Exploratory study: Exam scores
Comparison between categories of working memory (page 131)

Tests of Between-Subjects Effects

Dependent Variable: Exam scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	736.530(a)	2	368.265	1.677	.189
Intercept	990847.033	1	990847.033	4512.480	.000
CATWMC	736.530	2	368.265	1.677	.189
Error	64117.152	292	219.579		
Total	1074944.000	295			
Corrected Total	64853.681	294			

a R Squared = .011 (Adjusted R Squared = .005)

6.Exploratory study: SCG scores
Comparison between categories of working memory (page 131)

Tests of Between-Subjects Effects

Dependent Variable: SCG test scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	18.802(a)	2	9.401	.876	.418
Intercept	77019.694	1	77019.694	7172.755	.000
CATWMC	18.802	2	9.401	.876	.418
Error	3135.441	292	10.738		
Total	81461.090	295			
Corrected Total	3154.244	294			

a R Squared = .006 (Adjusted R Squared = -.001)

7.Exploratory study:SCG test scores
Comparison between categories of field dependency (page 134)

Tests of Between-Subjects Effects

Dependent Variable: SCG test scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	143.415(a)	2	71.707	6.954	.001
Intercept	78412.937	1	78412.937	7604.742	.000
CATFD	143.415	2	71.707	6.954	.001
Error	3010.829	292	10.311		
Total	81461.090	295			
Corrected Total	3154.244	294			

a R Squared = .045 (Adjusted R Squared = .039)

8.Exploratory study:Exam scores
Comparison between categories of field dependency (page 134)

Tests of Between-Subjects Effects

Dependent Variable: Exam scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1122.317(a)	2	561.159	2.571	.078
Intercept	1010690.474	1	1010690.474	4630.712	.000
CATFD	1122.317	2	561.159	2.571	.078
Error	63731.364	292	218.258		
Total	1074944.000	295			
Corrected Total	64853.681	294			

a R Squared = .017 (Adjusted R Squared = .011)

9.Experimental study: SCG test scores
Comparison between experimental group and comparison group (page 171)

Ranks

	Gender	N	Mean Rank	Sum of Ranks
SCG test scores	1	370	352.11	130280.50
	2	275	283.83	78054.50
	Total	645		

Test Statistics(a)

	SCG test scores
Mann-Whitney U	34349.500
Wilcoxon W	78054.500
Z	7.182
Asymp. Sig. (2-tailed)	.000

a Grouping Variable: Group

10.Experimental study: SCG test scores
Comparison between gender in experimental group (page 172)

Group Statistics

	gender	N	Mean	Std. Deviation	Std. Error Mean
SCG test scores	male	101	3.8515	1.96156	.19518
	female	269	3.4126	1.74834	.10660

Independent Samples Test

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
SCG test score	Equal variances assumed	2.434	.120	1.813	368	.072
	Equal variances not assumed			1.673	163.136	.080

11.Experimental study: SCG test scores
Comparison between gender in comparison group (page 173)

Group Statistics

	sex of respondent	N	Mean	Std. Deviation	Std. Error Mean
SCORE	male	57	2.65	1.408	.186
	female	218	2.45	1.313	.089

Independent Samples Test

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
SCORE	Equal variances assumed	.349	.555	1.007	273	.315
	Equal variances not assumed			.966	83.248	.337

12.Experimental study: SCG test scores
Comparison between programmes of study in experimental group (page 173)

Group Statistics

	programme of study	N	Mean	Std. Deviation	Std. Error Mean
SCG test scores	Math	295	3.6305	1.80770	.10525
	Non-maths	75	3.1467	1.81356	.20941

Independent Samples Test

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
SCG test scores	Equal variances assumed	.006	.940	2.068	368	.039
	Equal variances not assumed			2.064	114.271	.041

13.Experimental study: SCG test scores
Comparison between programmes of study in comparison group (page 174)

Group Statistics

	programme of study	N	Mean	Std. Deviation	Std. Error Mean
SCG test scores	maths ed	217	2.52	1.337	.091
	it ed	58	2.40	1.324	.174

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
SCG test scores	Equal variances assumed	.430	.512	.606	273	.545
	Equal variances not assumed			.610	90.552	.544

14.Experimental study: Exam scores
Comparison between experimental group and comparison group (page 175)

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Exam scores	1	228	64.66	13.365	.885
	2	164	65.20	13.597	1.062

Independent Samples Test

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
Exam scores	Equal variances assumed	.013	.908	-.390	390	.697
	Equal variances not assumed			-.389	347.698	.698

15.Experimental study: Exam scores
Comparison between gender in experimental group (page 176)

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Exam scores	male	65	58.58	14.255	1.768
	female	163	67.08	12.219	.957

Independent Samples Test

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
Exam scores	Equal variances assumed	2.833	.094	-4.514	226	.000
	Equal variances not assumed			-4.225	103.484	.000

16.Experimental study: Exam scores
Comparison between gender in comparison group (page 176)

Ranks

	Gender	N	Mean Rank	Sum of Ranks
Exam scores	male	43	67.29	2893.50
	female	121	87.90	10636.50
	Total	164		

Test Statistics(a)

	Exam scores
Mann-Whitney U	1947.500
Wilcoxon W	2893.500
Z	-2.446
Asymp. Sig. (2-tailed)	.014

a Grouping Variable: Gender

17.Experimental study: HFT scores
Comparison between experimental and comparison groups (page 177)

Ranks

	Group	N	Mean Rank	Sum of Ranks
HFT scores	1	228	190.29	43386.00
	2	164	205.13	33642.00
	Total	392		

Test Statistics(a)

	HFT scores
Mann-Whitney U	17280.000
Wilcoxon W	43386.000
Z	-1.286
Asymp. Sig. (2-tailed)	.198

a Grouping Variable: Group

18.Experimental study: HFT scores
Comparison between gender in experimental group (page 178)

Group Statistics

	Gend	N	Mean	Std. Deviation	Std. Error Mean
HFT scores	male	65	8.22	3.034	.376
	female	163	7.98	3.064	.240

Independent Samples Test

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
HFT scores	Equal variances assumed	.087	.768	.522	226	.602
	Equal variances not assumed			.524	118.891	.601

18.Experimental study: HFT scores
Comparison between gender in comparison group (page 178)

Group Statistics

	sex of respondent	N	Mean	Std. Deviation	Std. Error Mean
FD	male	43	8.95	3.773	.575
	female	121	8.48	3.559	.324

Independent Samples Test

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
HFT scores	Equal variances assumed	.652	.421	.739	162	.461
	Equal variances not assumed			.718	70.304	.475

19.Experimental study: Exam scores and SCG test scores
Comparison between field dependency categories in experimental group (page 180)

Descriptives

		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Exam scores	1	75	64.00	12.160	1.404	23	84
	2	88	64.03	14.063	1.499	30	90
	3	65	66.26	13.787	1.710	25	90
	Total	228	64.66	13.365	.885	23	90
SCG test scores	1	75	2.63	1.523	.176	0	7
	2	88	3.67	1.830	.195	0	8
	3	65	3.89	1.659	.206	1	8
	Total	228	3.39	1.764	.117	0	8

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
Exam scores	Between Groups	233.864	2	116.932	.653	.522
	Within Groups	40311.452	225	179.162		
	Total	40545.316	227			
SCG scores	Between Groups	67.023	2	33.511	11.795	.000
	Within Groups	639.236	225	2.841		
	Total	706.259	227			

20.Experimental study: Exam scores and SCG test scores
Comparison between field dependency categories in comparison group (page 180)

Descriptives

		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Exam scores	1	62	66.08	13.175	1.673	30	91
	2	57	64.88	14.982	1.984	24	91
	3	45	64.38	12.514	1.865	37	82
	Total	164	65.20	13.597	1.062	24	91
SCG test scores	1	62	2.26	1.436	.182	0	7
	2	57	2.09	1.258	.167	0	5
	3	45	3.16	1.043	.156	1	5
	Total	164	2.45	1.344	.105	0	7

ANOVA

		Sum of Squares	df	Mean Square	F	Sig
EXAM	Between Groups	84.441	2	42.221	.226	.798
	Within Groups	30049.315	161	186.642		
	Total	30133.756	163			
SCORE	Between Groups	32.163	2	16.081	9.869	.000
	Within Groups	262.343	161	1.629		
	Total	294.506	163			

Multiple Comparisons

Bonferroni

Dependent Variable	(I) CATFD	(J) CATFD	Mean Difference (I-J)	Std. Error	Sig.
EXAM	1	2	1.20	2.507	1.000
		3	1.70	2.675	1.000
	2	1	-1.20	2.507	1.000
		3	.50	2.724	1.000
	3	1	-1.70	2.675	1.000
		2	-.50	2.724	1.000
SCORE	1	2	.17	.234	1.000
		3	-.90(*)	.250	.001
	2	1	-.17	.234	1.000
		3	-1.07(*)	.255	.000
	3	1	.90(*)	.250	.001
		2	1.07(*)	.255	.000

* The mean difference is significant at the .05 level.

21.Stage three research: DSBT, HFT & MC test scores Comparison between gender (page 193 - 203)

	Gender	N	Mean	Std. Deviation	Std. Error Mean
DSBT scores	1	63	6.00	1.368	.172
	2	186	6.19	1.483	.109
HFT scores	1	63	8.87	2.808	.354
	2	186	8.30	2.945	.216
MC test score	1	63	19.29	6.087	.767
	2	186	17.83	5.669	.416

Independent Samples Test

		Levene's Test for Equality of Variances				
		F	Sig.	t	df	Sig. (2-tailed)
DSBT scores	Equal variances assumed	3.232	.073	-.912	247	.362
	Equal variances not assumed			-.950	115.106	.344
HFT scores	Equal variances assumed	.234	.629	1.360	247	.175
	Equal variances not assumed			1.393	111.607	.166
MC test score	Equal variances assumed	.373	.542	1.731	247	.085
	Equal variances not assumed			1.671	100.863	.098

22.Stage three research: MC test scores
Comparison between working memory capacity & field dependency categories
(page 204)

Descriptives

MC test scores

	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1	83	15.84	6.504	.714	2	34
2	82	18.67	4.619	.510	11	33
3	84	20.06	5.349	.584	9	32
Total	249	18.20	5.800	.368	2	34

ANOVA

MC test scores

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	769.581	2	384.791	12.501	.000
Within Groups	7571.776	246	30.780		
Total	8341.357	248			

Multiple Comparisons

Dependent Variable: MC test scores
Bonferroni

(I) CATWM	(J) CATWM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-2.83(*)	.864	.004	-4.91	-.75
	3	-4.22(*)	.859	.000	-6.29	-2.15
2	1	2.83(*)	.864	.004	.75	4.91
	3	-1.39	.861	.324	-3.46	.69
3	1	4.22(*)	.859	.000	2.15	6.29
	2	1.39	.861	.324	-.69	3.46

* The mean difference is significant at the .05 level.

Descriptives

MC test scores

	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1	83	17.64	5.562	.611	7	31
2	84	18.24	5.963	.651	2	32
3	82	18.72	5.884	.650	3	34
Total	249	18.20	5.800	.368	2	34

ANOVA

MC test scores

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	48.414	2	24.207	.718	.489
Within Groups	8292.944	246	33.711		
Total	8341.357	248			

Multiple Comparisons

Dependent Variable:Mc test scores
Bonferroni

(I) CATFD	(J) CATFD	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.60	.899	1.000	-2.77	1.57
	3	-1.08	.904	.699	-3.26	1.10
2	1	.60	.899	1.000	-1.57	2.77
	3	-.48	.901	1.000	-2.65	1.69
3	1	1.08	.904	.699	-1.10	3.26
	2	.48	.901	1.000	-1.69	2.65

Between-Subjects Factors

		N
CATFD	1	83
	2	84
	3	82
CATWM	1	83
	2	82
	3	84

Tests of Between-Subjects Effects

Dependent Variable: Mc test scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	907.042(a)	8	113.380	3.660	.000
Intercept	81133.798	1	81133.798	2619.221	.000
CATFD	45.889	2	22.944	.741	.478
CATWM	795.172	2	397.586	12.835	.000
CATFD * CATWM	91.828	4	22.957	.741	.565
Error	7434.315	240	30.976		
Total	90791.000	249			
Corrected Total	8341.357	248			

a R Squared = .109 (Adjusted R Squared = .079)