Difficulties in Solving Algebra Story Problems with Secondary Pupils

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Between the idea
And the reality
Between the motion
And the act
Falls the shadow

T.S.Eliot

Abstract

The purpose of this study was to investigate students capability in applying mathematics in real life. In order to do this it was decided to explore students' performance in representing algebra story problems. This research investigates the reasons for the difficulties facing the majority of students in representing algebra story problems. The research took place in a town called Trikala in Greece and a sample of 90 high school students aged between 15-17 years from a private support school was used.

Two cognitive factors believed to have an important influence on pupil's performance in representing word problems were measured, namely: working memory space capacity and field-dependence/independence. To determine the working memory space capacity of the students, the Digit Backwards Test (D.B.T.) was used and, to measure the degree of field-dependence/independence of the pupils, the Hidden Figure Test (H.F.T) was used. In order to determine students' attitudes towards mathematics, a questionnaire was designed which tested factors like motivation, self confidence, influence from the close environment and students' preferences for disciplines of the curriculum.

In order to test students capability in representing algebra story problems and the role that working memory space (X-space) and field-dependence/independence have in success in this task, a mathematics test was designed. The test included 10 'compare' algebra story problems taken from the literature or produced for the sake of this project. The students were asked to write down the equation that represents the given statement. The information processing model and other approaches to the difficulties students have with these problems were applied to design this mathematics test and also to put the problems onto a scale according to the difficulty (Z-demand) they placed on the pupils working memory capacity.

It was concluded that working memory space and field-dependence/independence were significant predictors for problem representation success. Thus, high working memory space capacity students performed better in the mathematics test than their intermediate or low working memory space capacity counterparts. Failure occurred in the mathematics test when the Z-demand was quite close to the pupil's measured working memory capacity as a possible result of overloading of the working memory space. Students' performance in the test improved as the pupils went from being field-dependent to field-independent.

Students' attitudes towards mathematics influences achievement in the mathematics test. Motivation, self confidence, father's level of education, are positively correlated factors to students' achievement. Pupils who have a middle preference between mathematics and language classes had the best performance. Knowledge of language is a significant predictor for success in representing algebra story problems.

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Chapter One

Introduction

Mathematics, as an educational discipline, has been at the centre of the education process for much of the history of humankind. There are numerous reasons for this. In this research, 95% of the students' response to the question: "why do you think mathematics is important", was that mathematics is important for everyday life. Some of them specified that mathematics is important for dealing with everyday problems and some that it is important for the way we (humans) think. However, although almost everyone agrees that mathematical knowledge is important, mathematics is not applied much in our lives. Many people live a normal life, communicate, and exchange goods and ideas without having even a primary knowledge of simple mathematics. This seems to be paradox. According to Vygotsky (1978), the pedagogical movements that urged the teaching of classical languages, ancient civilisations and mathematics have assumed that, regardless of the irrelevance of these particular subjects for daily living, they were of the greatest value for the pupils' mental development. Knowledge of mathematics, even if it does not seem to be applied often in everyday life, is important, not just for surviving in a society that grows, but for the way someone thinks. The way someone thinks is the way he sees life and the way he lives.

Teaching mathematics is teaching a specific way of thinking and processing information. It is very important to learn how to deal with abstract concepts, using logical steps, rules and restrictions to come to the right conclusion.

School mathematics should be applied in everyday problems whenever this is possible. Calculations, solving equations or creating analogies, should work as tools in everyday living. Students should be exposed to this dual nature of mathematics applications; applying mathematics to mathematics and then applying mathematics to real world (Sharma, 1988). Applying mathematics, whenever it is possible, seems to give meaning and purpose to the mathematical studies of the students.

The focus of this research is high school students from Greece. Mathematics in Greece is at the centre of the education system. The aims of teaching mathematics in lower secondary education in Greece, as the Ministry of Education has introduced them, are first of all that the students comprehend and complete the knowledge they have gained from primary school, so that they are supplied with mathematical knowledge necessary for living and further studying and development. Another aim is that the students combine their experiences with applications from everyday life, technology and other applied sciences so as to develop positive attitudes toward mathematics.

Are the above aims fulfilled by the way mathematics is taught in Greek schools? Do the students finally comprehend the mathematical concepts they have dealt with? Are the students leaving lower secondary education ready to apply their knowledge to everyday living, whenever this is possible? These are the questions that prompted the author to investigate in this research.

1.1 Mathematics and the Real World

On seeking to investigate the relationship between mathematics and reality, the question whether mathematics is discovered or invented rapidly emerges as a fundamental issue. Philosophy and epistemology have puzzled for many centuries over this question. There are two major philosophical schools in this area: absolutism and fallibilism (or social constructivism).

Absolutist philosophies view mathematics as an objective, absolute and certain knowledge, which rests on the firm foundation of deductive logic and not on an empirical basis. Among twentieth century perspectives in the philosophy of mathematics, Logicism, Formalism and, to some extent, Intuitionism and Platonism, can be considered to be absolutist in this way (Ernest, 1991). According to them, mathematical ideas exist separately of humans, and humans must discover them. Mathematical knowledge is timeless, even if new theories and truths are discovered every day. They are suprahuman, ahistorical, culture and value free and with universal validity because "mathematics is already there, to be discovered", as Roger Penrose, a modern mathematician, argues (Penrose, 1989) and he is not alone. Most mathematicians share this view, from the early years till now.

On the other hand, fallibilism, a philosophical-epistimological theory, argues that mathematics, as with all other human knowledge , is not passively received but actively built by humans, in a human environment. Every mathematical idea was invented by a person or a group of persons, in a social environment and carries with it the ideas, beliefs, prejudices, history, social state, power relations, of this environment. Mathematical certainty rests on socially accepted rules of discourse embedded in our "forms of life" (Wittgenstein, 1956). This makes the mathematical ideas more subjective. Truth in mathematics is not absolute, but must always be understood as relative to a social background system. Mathematical knowledge is understood to be fallible and eternally open to revision, both in terms of its proofs and its concepts (Lakatos, 1976). It is no longer seen as defined by a body of pure and abstract knowledge which exists in a suprahuman, objective realm (Tymoczko, 1986).

Mathematical ideas grow as the years go by, partly because real life problems impose the necessity for mathematics to give a solution. In the history of mathematics, there are plenty examples of real life problems determining new mathematical concepts and even new branches in mathematics. The need to calculate and collect taxes forced the progress of calculations. Trigonometry and spherical geometry were developed for the needs of astronomy or navigation. Statistics was born from gambling games and insurance policies, and modern algebra for the needs of technology and exchanging of information.

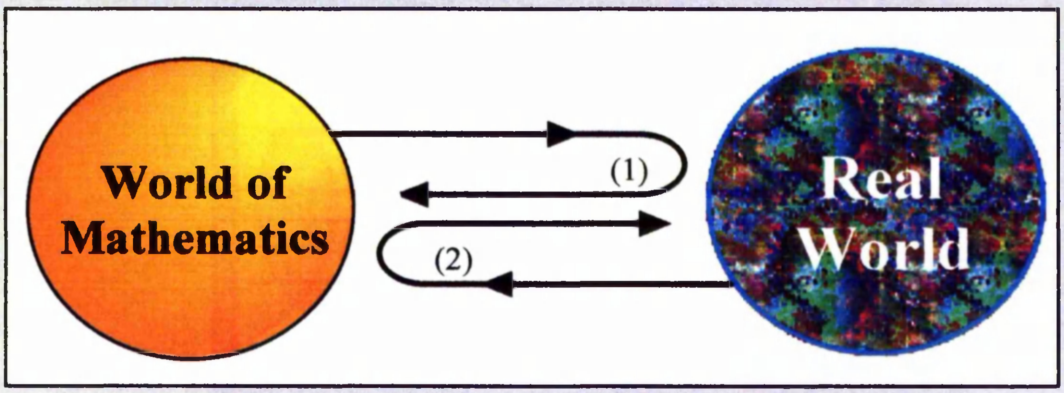
However, mathematics also produces ideas as an internal procedure. Based on its logic, rules and concepts, mathematics expands in other directions which are sometimes very abstract. Dealing with mathematics is all about following specific rules, logical steps and algorithms in order to reach a target. Fallibilists believe that these rules are invented by humans, almost in the same way as with the rules of a game like chess. This knowledge is to a large extent necessary, stable and autonomous, like the rules of a game, even if humans invented it in the first place.

Mathematics differs from other sciences. Unlike physics, where there is just one world to focus on, mathematics allows the existence of more than one world. Knowing what is true or false in mathematics is not as simple as in other sciences. For example, in geometry, two parallel straight lines are not connected in Euclidian geometry although, in the same time, they could be connected in non-Euclidean geometry. In the world of mathematics, many different worlds are allowed, like Euclidean and non-Euclidean geometry. According to fallibilist philosophy, mathematics is producing different worlds without the need to reject the old ones.

Mathematical ideas (like concepts, symbols, rules, theorems) build a world different from the real world where we live. The real world, which is the physical world different from the world of ideas, is a world of 'noise', full of information, much of which is irrelevant. Abstraction must take place in order that humans are able to think and make decisions. According to Sawyer (1959), abstraction is a process of forgetting unimportant details and, without abstraction, thought would be impossible. For example, when we are interested in the speed of a train and the time it is going to take to reach the next station, we do not pay attention to the colour of the train or the gender of the driver or the sightseeing around. If we took all this information under consideration, it would be impossible to come to any conclusion.

Mathematics is all about abstraction and generalisation. Even when simple calculations are taking place, they are at an abstract level, distant from reality. Nothing in nature is 2 or 3. There are two apples, two chairs and so on, but numbers like that only belong to a different world. That makes mathematics exist in another dimension from that of real life. If we assume that the figure below (Figure 1.1) represents the relationship between the two worlds, the real world and the world of mathematics, then there are two routes that connect these two worlds.

Figure 1.1: Mathematics and the Real World



Route (1), the one starting from the world of mathematics reaching the real world and coming back, is a process of making concrete the abstract concepts of mathematics. According to Sharma (1987), students must first have a great experience with concrete manipulations in order to be able to deal with abstract concepts. He argues that "without a sufficient number of appropriate concrete mathematical experiences that provide sufficient modelling for mathematical concepts, at the early stage in the child's development, the child will encounter needless learning difficulty in the future". There are examples of students in high school, still using their fingers, secretly, whenever they do calculations. This route could be argued to serve a function of connecting mathematics notation to their concrete representation that exists in the real world.

As far as the other route is concerned, *route (2)* (Figure 1.1), which begins from the real world, reaching the world of mathematics and coming back, this is what problem solving in mathematics is all about. In order to give solutions in real problematic situations, they have to move to the world of mathematics, where there is not so much noise and seek a solution there. For this solution to be useful, we have to come back to the real world and translate it to real language if this is possible. Two representations are taking place in this route: first of all, a representation of the real problem in a mathematical notation and secondly, when mathematics supplies a solution, this solution needs to be represented in real language. Apart from specific areas of mathematics that are directly connected with real life, most of mathematical ideas are difficult to be applied in real life situations.

The students capability of completing the second route (*route (2)* in Figure 1.1) successfully is the focus of this research. There are many different ways of investigating whether students who have the necessary mathematical knowledge, are able to use it in giving solutions to problematic situations that are or could be real. One of these ways is by testing the students' success in representing algebra story problems (or word problems). According to Sharma (undated), a word problem is a computation requested in linguistic form. For example:

> Tom has 5 marbles. Anna has 12 marbles more than Tom.
> How many marbles does Anna have?

"Word problems are the clearest example of the students' understanding and their ability to demonstrate application of mathematics skills acquired" (Sharma, Undated). Representing an algebra story problem means to create an equation which gives solution to the problem given. The word representation is used because the same problem which was presented in linguistic form now needs a re-presentation in symbolic form. According to Clement *et al.* (1981), students "must learn to apply mathematics; that is, they must translate a problem usually expressed in words into algebraic notation and retranslate a solution back into words. Thus, translation skills are critically important in learning mathematics".

1.2 The Aims of This Research

Educational research at different ages, and classroom experience, indicates considerable failure and rejection from students all over the world to this kind of problem. Students appear to have great difficulties in making the connection between the two worlds: the world of mathematics and the real world. This is determined by the difficulty students have in representing even simple algebra story problems in a mathematical notation (Clement *et al.* 1981; Hart, 1981; Fisher, 1988; Sharma, undated; Hasapis, 1993; Kourkoulos, 1996).

The aim of this research, therefore, is to explore the difficulties students have in making this translation from real to mathematical language; from practical situations to mathematical notation. Many factors may be responsible for the difficulties the students have. The way mathematics is taught in school or the way the whole education system functions could be a reason. Other reasons could be social or psychological factors like students' attitudes towards mathematics.

"From the kindergarten to high school, mathematics is not comprehended. Don't you think it's about time to consider how it might be possible to make it easy, for hundreds of capable students, to understand? What we have to change immediately is not the things, but the way we look and hear to things and human beings" (Baruk, 1985). According to the Israeli psychologist Reuven Feuerstein (1980), children can have difficulties in learning from experience or in responding to teaching because of cognitive deficiencies. In recent years, research in education has attempted to take into account educational psychology models and the students' cognitive structure. The cognitive approaches are concerned with how humans process the information given from the environment. They investigate the reasons why we pay attention to some things and not to others and how we use this information.

The Information Processing approaches in education studies the flow of information in the students' cognitive system. This flow process consists of: an input, an output and a mental operation which occurs between input and output. "It's time to look at the students mind and teaching them accordingly" (Johnstone, 1997). The Information Processing Model (presented in chapter two), which is used in this project, is proposing an interpretation of how learning is functioning, arising from a number of psychological schools of thought. "An understanding of the learning process may influence the way we teach and the way we react when the thing's not going well" (Johnstone, 1997).

1.3 The Structure of this Research

This study seeks to investigate some possible reasons for the difficulties with algebra story problems representation. In order to do this, the following areas are considered:

- In chapter two, there is a presentation of the major learning theories and models that provide the main theoretical basis for this study.

- In chapter three, there is a review of the major factors that affect success in problem representation as the international research has suggested. The aims is to determine the reasons for the difficulties that the students have in making the translation from real language to mathematics notation and to design the test materials used in this research accordingly.

- In chapter four, there is a brief presentation of the way the Greek education system functions and the problems within the system, in order to become familiar with the education environment from which the sample of this research comes.

- In chapter five, the Information Processing Model is explored further. In this chapter there is a presentation of the methodology of the study, the test materials and the data analysis of the the first stage of the research. This study was applied in a Greek private high school[1] . The first stage took place in December 2000 and the aim was to explore the affect of some cognitive factors that influence success in representing word problems.

- The second stage of this research is presented in chapter six. This stage took place in April 2001 and the aim was to investigate other possible social-psychological factors that may influence success in the same problems.

- Finally, in chapter seven, attention is drawn to the conclusions and implications for teaching and assessments which were made from the above studies.

[1] *The nature of this kind of school, because it is different from private schools in the United Kingdom, is briefly presented in chapter four.*

Chapter Two

Learning Theories

Education involves two major processes: teaching and learning. Before being able to take decisions about what would be the best way to teach something, we should try to understand how learning occurs. There are many different approaches from different schools of thought about how humans learn. This research focus on the cognitive approach. Many authors have formulated models in order to represent the construct of cognitive structure. Ausubel's theory and model is one of the most important theories that have influenced research in education. The Information Processing Model which is used in this project has used Ausubel's model as well as other theories. Ausubel's theory, the Information Processing Model, and theories about the different cognitive styles of the students are discussed in this chapter.

2.1 Background Theories

There are two major psychological schools which tried to investigate the way humans learn: the behaviouristic school and the cognitive school. The behaviouristic school, led by B.F. Skinner, was the one that started to study the human learning process (Smith *et al.*, 1998). Based on observations of the way animals learn they approached human learning as a *response acquisition*. Students were perceived to be passive beings, who gain knowledge through a reward-and-punishment process. Behaviourism failed to supply any explanation about the mental processes taking place in human learning, because they thought of the human mind as a 'black box'. They argued that it is not possible to see what happens inside this 'black box'.

On the other hand, cognitivism focused on the mental rather than on the behavioural. The cognitive theories grew in the 1970s and 1980s. Much research has taken place in real classroom situations by cognitive psychologists over the years in order to examine the process of learning. The cognitive approach perceives learners as information processors - a metaphor borrowed from computer science. According to them, it is important to understand how humans obtain, process, and use the information taken from the environment, in order to understand how they learn. Many models have been suggested to represent the structure of this process.

Along with the information processing models, the constructivistic approach is another important cognitive theory. Influenced by the Swiss psychiatrist Jean Piaget (1896-1980), his theories and experimental results, constructivistic theories grew in the 1980s and 1990s and influenced educational research worldwide for many years and still do. Ausubel's meaningful verbal learning model, a theory of significant importance for the educational thought, also emerged from the constructivistic framework.

2.2 Ausubel's Theory and Model

Ausubel's model is based on real classroom learning situations, and two fundamental dimensions of the learning process are considered in this model. The first dimension has to do with the different ways information is made available to the learner (*reception* or *discovery*). The second dimension has to do with the degree of meaningfulness (*rote* or *meaningful*), by which the learner assimilates the information into his existing cognitive structure. These two dimensions are assumed to be unrelated (Johnstone, 1997).

2.2.1 Reception versus Discovery Learning

As far as the first dimension is concerned, Ausubel *et al.*(1978) argues that people acquire knowledge primarily through reception rather than through discovery, as Bruner (1966) believed. According to Ausubel, concepts, principles and ideas are presented and understood, not discovered. Education is a condensed way of presenting a part of the existing knowledge in an assimilable way, in order to save time, because there is not enough time to rediscover everything.

Discovery learning is based on a learner-centred rather than a teacher-centred view of the teaching/learning process. In discovery learning, the learners are supposed to use the learning materials given to them and discover the new knowledge, organise it and construct the links and relationships with their existing knowledge. On the other hand, in direct or reception learning, it is the teacher who organises the teaching materials and presents it to the learners in relatively final form. "In reception learning the entire content of what is to be learned is presented to the learners in final form...and the essential feature of discovery learning is that the principal content of what is to be learned is not given but must be discovered by the learner before it can be incorporated into the student's cognitive structure" (Ausubel *et al.*, 1978). They indicated that depending on what happens after the content to be learned is linked to the student's cognitive structure, both reception and discovery learning can be classified either as meaningful or as rote learning.

2.2.2 Meaningful versus Rote Learning

Meaningful learning is the most important idea in Ausubel's theory. It occurs when the new knowledge can be related to the knowledge the learner already has. Previous knowledge is a key concept in Ausubel's theory. The principal idea of his theory is that what you know controls what and how you learn. New knowledge interacts in a non-arbitrary way in cognitive structure. According to Novak (1984), the non-arbitrary incorporation of new knowledge is a conscious effort of the learner to relate new knowledge to knowledge he/she already has in his/her mind; substantive learning is a conscious effort by the learner to identify the key ideas in new knowledge and to relate them to other ideas.

McClelland (1982), argues that three conditions have to be met in order for meaningful learning to be achieved:

> i. *The material itself must be meaningful, that is, it must make sense or conform to experience.*
> ii. *The learner must have enough relevant knowledge for the meaning in the material to be within grasp.*
> iii. *The learner must intend to learn meaningfully, that is, must intend to fit the new material into what is already known rather than to memorise it word by word.*

On the other hand, rote learning can be considered as the learning in which these conditions do not exist. Rote learning occurs when there are no relevant concepts available in the learner's cognitive structure to interact with the new knowledge. It results in arbitrary verbatim incorporation of new knowledge into cognitive structure.

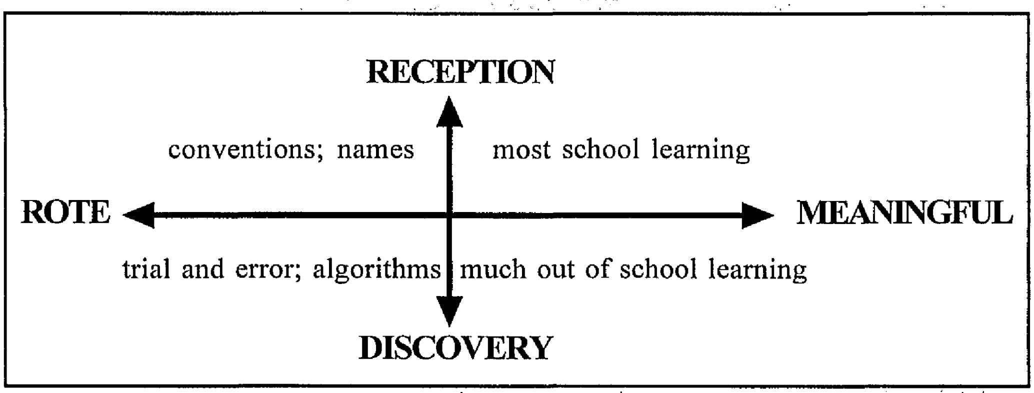
Ausubel & Robinson (1969) demonstrated that:

> *"meaningful and rote learning are not dichotomies, however learning will be increasingly rote to the extent that:*
>
> *i) the material to be learned lacks logical meaningfulness,*
> *ii) the learner lacks the relevant ideas in his own cognitive structure*
> *iii) the individual lacks a meaningful learning set.*
>
> *Any of these three conditions alone will be likely to lead to rote learning".*

To summarise all this, meaningful learning can be described as "good, well-integrated, branched, retrievable, and usable learning", while rote learning is "at best, isolated and boxed learning that relates to nothing else in the mind of the learner" (Johnstone, 1997).

According to Ausubel, both reception and discovery learning can be either meaningful or rote learning. A pattern showing the 'rote-meaningful' learning continuum and its relation to the 'reception-discovery' mode of information acquisition was presented by Ausubel *et al.* (1978) and it is shown in Figure 2.1.

Figure 2.1: The dimensions of learning



Ausubel et al. (1978)

Other key concepts in Ausubel's theory are: subsumption, progressive differentiation, superordinate learning, advance organiser. Each is now discussed in turn.

2.2.3 Subsumption

According to Ausubel & Robinson (1969), subsumption is an indispensable process for meaningful learning. He has used the term 'subsumption' to identify a concept, principle, or generalising idea that the learner already has in his mind (which can provide an association anchorage for the new knowledge). When the existing concept subsumes the new knowledge, this can provide interactions for meaningful learning. New knowledge is usually incorporated (subsumed) into more general concepts (Novak, 1978). Ausubel argues that cognitive structure is hierarchically organised. That means that the less inclusive sub-concepts and details of specific data are organised under the most inclusive concepts. This might suggest that instructions should be given to the learners from the most general to the specific and less inclusive.

In the process of subsumption, even if the anchoring concept and the new knowledge are both modified, they continue to hold separate identities. When new material is almost similar to the existing material, then there is '*derivate subsumption*' as the new material could have been derived from the old one. On the other hand, there is '*correlative subsumption*', when the new material is not similar to the anchoring one: therefore, it requires some change in the existing cognitive structure.

2.2.4 Progressive Differentiation.

Progressive differentiation is the constant modification and elaboration of the concepts in cognitive structure which makes them more precise and more exclusive As the new knowledge is subsumed into the existing knowledge, it interacts and modifies it and the whole new matrix now becomes more elaborate and new linkages form between concepts. This is what Ausubel called 'progressive differentiation'. Novak, (1978) argues that progressive differentiation begins in early childhood (2 years old or less) and continues throughout adult life. For instance, at the beginning, the concept 'animals' in a child's mind might just contain the difference between cats and dogs; although as he/she grows up and learns concepts like mammals, birds etc., the first concept becomes more precise and continues to differentiate as he/she learns more.

2.2.5 Superordinate Learning

As Ausubel *et al.* (1978) argued, in superordinate learning, the previously learned concepts are seen as elements of a larger and more exclusive idea and the acquisition of superordinate meanings occurs more commonly in conceptual than in propositional learning. For example, when children learn more than the familiar concepts of eagle, crow, hawk then they may all be subsumed under the new concept wild birds.

2.2.6 Advance Organiser

Ausubel and Robinson (1969) introduced the concept of advance organiser as "an advanced introduction of relevant subsuming concepts (organisers) which can facilitate the learning and retention of unfamiliar but meaningful verbal material". The major function of the organiser that is introduced in advance of the material to be learned is, according to Novak (1979), to bridge the gap between what the learner already knows and what he/she needs to know before he/she can successfully learn the new concept. West and Fensham (1974) described it as "a verbal statement presented to the learner before the detailed new knowledge".

According to Ausubel, the advance organiser is introduced in two cases:

> i. *When the learner does not possess appropriate subsumers e.g. when the new concept is completely novel and the learner lacks another concept to relate to it.*
>
> ii. *When the learner possesses relevant subsuming concepts, although these concepts are inadequately developed and it is to be recognised and related to the new concepts.*

The advance organiser influences teaching materials in two ways: i) to bring to mind prior knowledge that is relevant to the lesson be taught. Therefore to increase familiarity and meaningfulness to the new learning task. ii) To provide an anchorage to the learning material 'in the form of relevant and appropriate subsuming concepts at a proximate level of inclusiveness'. This helps to make the new concepts more easily recalled (Ausubel and Robinson, 1969).

Ausubel introduced two types of organisers: the '*expository organiser*' and the '*comparative organiser*' to be applied in different situations. When the teaching material is completely novel, the expository organiser is used in order to make use of description or exposition of concepts relevant to the new one. The expository organiser is used in order to expand a concept (subsume) in its general characteristics to which the new material can be related. When the teaching material is somewhat familiar, the comparative organiser is used and it makes use of similarities and differences between the new material and the existing cognitive structure of the learner.

Ausubel summed up his own work in the phrase:

> *"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."*
>
> *(Ausubel, 1968)*

It would be very useful if we tried to apply this phrase in everyday classroom conditions. Teachers should access students' previous knowledge before introducing a new concept and try to find out the best organiser for each case. Every individual is different from another depending on the things he/she already knows, and his/her way of making sense of the things around. Meaning is not a property of objects or concepts themselves. Objects or ideas acquire meaning in the learner's mind (Lefrancois, 2000). The learners build their own knowledge by themselves, in a unique way. Meaning is not something specific that can be taught directly but it is something that is constructed in the learners' mind by the learners. Learners are not 'empty pots to be filled' and information is not transmitted, but it is reconstructed idiosyncratically by each student (Johnstone, 1987). This approach to teaching and learning is also supported by the constructivist school.

2.3 Information Processing Theory

The cognitive approach to the question 'how humans learn' is concerned with theories and research on how humans process, store and retrieve the information they receive from the senses. In order to answer this question, cognitive psychology uses metaphors borrowed from the branch of computer science concerned with artificial intelligence. According to Kempa and Nicholls (1983), cognitive structure is a hypothetical construct referring to the organisation of concepts (or the pattern of the relationship between concepts) in memory.

In the psychology literature, there are many models of human information processing that are suggested by authors, to represent the cognitive structure. Most of them are influenced by the work of Atkinson and Siffrin (1971). Johnstone (1993a) introduced one such model, the Information Processing Model shown in Figure 2.2. This model suggests a simplified mechanism of the learning process.

2.3.1 The Information Processing Model

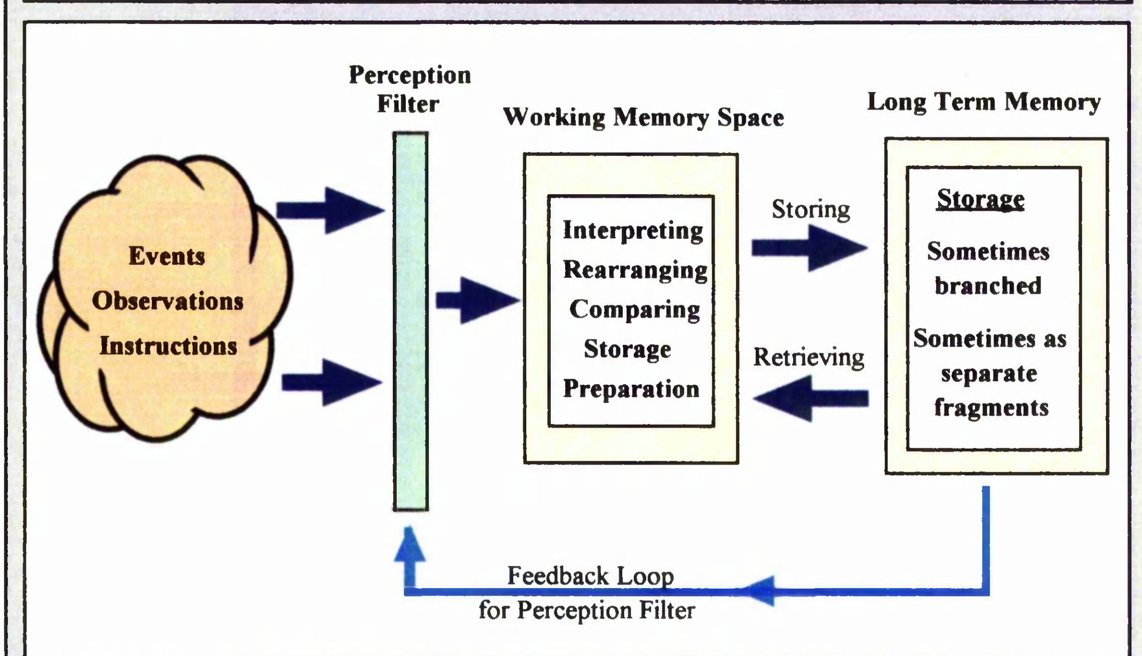
According to Ashcraft (1994), a standard information processing model should contain three major components:

- *sensory memory (sensory register or perception filter)*
- *short term memory (working memory or working memory space)*
- *long term memory*

There are differences between these three types of memory in the way the information processing functions and in their capacity.

According to these models, the information enters the system through the sensory memory and ends up to the working memory which interacts with the long term memory. Johnstone's (1993a) model includes all three major components of Ashcraft's (1994) theory: perception filter, working memory space, and long term memory, and adopts learning theories like that of Ausubel's importance of prior knowledge, Pascal-Leone's (1970) ideas of limited working memory space and the constructivist view of building the knowledge (Driver and Easley, 1978). This model suggests explanations of how learning has occurred and why learning is sometimes difficult or impossible.

Figure 2.2 : The Information Processing Model



Johnstone. (1993a)

2.3.2 Sensory memory - perception filter

Our sensory memory consists of our sensory registers, which are linked to the five senses: sight, hearing, taste, touch, and smell. Our senses are the links between ourselves and the environment around us. Through the senses we receive information from the environment and respond back to it. Most of the research work in the literature has focused on the vision and hearing sensory register.

Aschcraft (1994) describes two types of sensory memory: *visual sensory memory*, which receives visual stimuli, and *auditory sensory memory*, which receives auditory stimuli. According to Attkinson and Shiffrin multi-store model of memory (1968), there is a separate sensory system for each sense, each corresponding to a different sensory modality; auditory information, entering through ears, is initially stored in the auditory sensory memory (also labelled 'echoic memory' by Neisser (1967)); on the other hand, visual information entering the system through the eyes, is initially stored in the visual sensory memory, also known as 'iconic memory' (Neisser, 1967).

Studies support the idea that sensory memory holds the information of the input stimuli for very short time, about one-quarter to one-half of a second in iconic memory and no more than two or three seconds in echoic memory (Ashcraft, 1994).

The information-stimulus we receive every single moment of our lives is huge. It is impossible to pay attention and respond to every stimulus we receive. A big amount of this information is irrelevant and not essential (it could be called 'noise') and some of it is the useful information, the information that matters (this could be called 'signal'). There must be a procedure through which all the stimuli are 'filtered' and only some are chosen for attention allowing process and responding. In other words, everyone can distinguish the difference between the signal and the noise in his own way. This selection involves specific kind of criteria. According to White (1988), the selection of events is vital in learning, and what is selected by the learners is affected by their previous knowledge, attitude and abilities.

Also it depends upon:

> *i. the attributes of events: properties like absolute intensity of a stimulus motion and relative intensity of a stimulus*
> *ii. attributes of the observer: general level of alertness range of cognitive strategies available to the observer*
> *iii. interaction between events and the observer selection is affected by whether the observer finds the events unusual, interesting or understandable, and on the observer's construction of patterns and seeing events as a collection of meaningful units.*

In Johnstone's (1993a) model, the sensory memory can be identified with his perception filter. The way the filter is functioning is influenced by the long term memory (there is a feedback loop between the perception filter and the long term memory). Previous knowledge, preferences, likes and dislikes, biases, experiences, prejudices, beliefs (cultural, political, religious) control the way the learner selects from one huge amount of information only some pieces. As a second step, the selected information goes to the working memory where the manipulation is taking place.

2.3.3 Working Memory

Short term memory and *working memory* are often used interchangeably in the literature. Some authors prefer the use of short term memory (Atkinson & Schiffrin, 1971; White, 1988) although others use the term working memory (Baddeley, 1986; Johnstone, 1988; Schneider and Schiffrin, 1997). Johnstone (1984) gave an explanation for the distinction between short term memory and working memory. When someone is asked to memorise a set of numbers, like a telephone number, and then recall it in the same order within seconds, then no processing is taking place and the space is used completely as a short term memory. On the other hand, if the same person is asked to sum the numbers or recall them backwards, then, in this case, a working process has taken place and the space is called working memory. This can be defined as "that part of the brain where we hold information, work upon it, organise it, and shape it, before storing it in the long term memory for further use" (Johnstone, 1984). In this project the term 'working memory space' (a label used by Case (1985) who systematically examined the short term memory capacity of young children) is used, although, when there is a reference to another author, the term he has used will be retained.

There are two important functions of the working memory space (WMS). These are:

i. "It is the conscious part of the mind that is holding ideas and facts while it thinks about them. It is a shared holding and thinking space where new information coming through the perception filter consciously interacts with itself and with information drawn from the long term memory store in order to make sense.

ii. It is a limited shared space in which there is trade-off between what has to be held in conscious memory and the processing activities required to handle it, transform it, manipulate it and get it ready for storage in long term memory store. If there is too much to hold there is not enough space for processing; if a lot of processing required, it cannot hold much" (Johnstone, 1997).

The working memory space is characterised by a limitation in both the capacity for storage and the duration. There are many ways to measure the capacity of the WMS of the individuals. For many years, the *digit span test* has been used by the researchers. In this task, subjects are read a series of digits (e.g. '8 6 3') and must immediately repeat them back. If the subjects succeed in this, they are given a new series of digits with one more digit (e.g. '5 7 3 6') and so on. When mistakes begin to appear this means that the working memory cannot hold that long series of digits. It seems that the subjects are doing well with six or seven items; however, with eight or nine, mistakes start to happen. According to Reisberg (1997), subjects are more likely to remember the first few items on the list, which is known as the *primacy effect*, and also likely to remember the last items on the list, which is known as the *recency effect.*

However, there are other ways to measure working memory space capacity. For instance, another version of the digit span task is the *digit span backwards test* in which subjects are given a series of digits which they have to recall in reverse order, rather than the same order as in digit span test. This test measures not only the capacity of holding the information but the holding and working capacity of the working memory space.

The digit span backwards test is a symbolic test. There are tests using visual tasks in order to measure the WMS capacity. A comparison of the results of two tests is the most accurate way of measuring WMS capacity. The working memory space capacity depends on the age of the individual. Research with adults has indicated that the capacity of the working memory space is about 7 items, and probable no more than nine. Miller, (1956) argued that "7 plus-or-minus 2" 'chunks' of information can be held in the short term memory at a time.

It has to be clarified what 'chunks' means. It is much more difficult, for example, to recall 7 irrelevant letters than to recall 7 letters that make a word. This is the reason why the nature of the items plays a major role in the capability to recall it. Johnstone and Kellett (1980) described the term chunk to be that which the observer perceives or recognises as a unit; for example, a word, a letter or a digit. This is controlled by the student's previous knowledge, experience and acquired skills (Johnstone and El-Banna, 1986). Chunks are grouped information. It could be a single number, a letter, or many pieces of information grouped together by the learner. Consequently, chunking is the process through which the learner groups together pieces of information in a way that allows him to hold more information. According to White (1988), we 'chunk the world', that is we combine our sensations into a small number of patterns and so chunking is a function of knowledge. Because of the different ways of chunking, there are differences between the knowledgeable person (e.g. teacher, adult, expert) and the novice (e.g. student, child, beginner) in the size and number of the information perceived in a situation.

To summarise this, working memory has two functions, holding and thinking, which operate simultaneously in a limited, shared space (Baddeley, 1986). Working memory holds and processes the information coming from the perception filter. The operations that take place are: interpreting, rearranging, comparing, preparing information and interacting with the prior knowledge, which is stored in the long term memory and also with the perception filter for receiving and responding to information coming. In our working memory we keep the information on 'temporary hold', until we decide what to do with it: throw it away or store it in the long term memory.

2.3.4 Overloading of Working Memory

Working memory has a limited capacity. What happens when the information given to the learners exceeds his/her working memory capacity? Much research has explored this question.

According to Johnstone (1997), 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. Research in mathematics and science education presented below has indicated that:

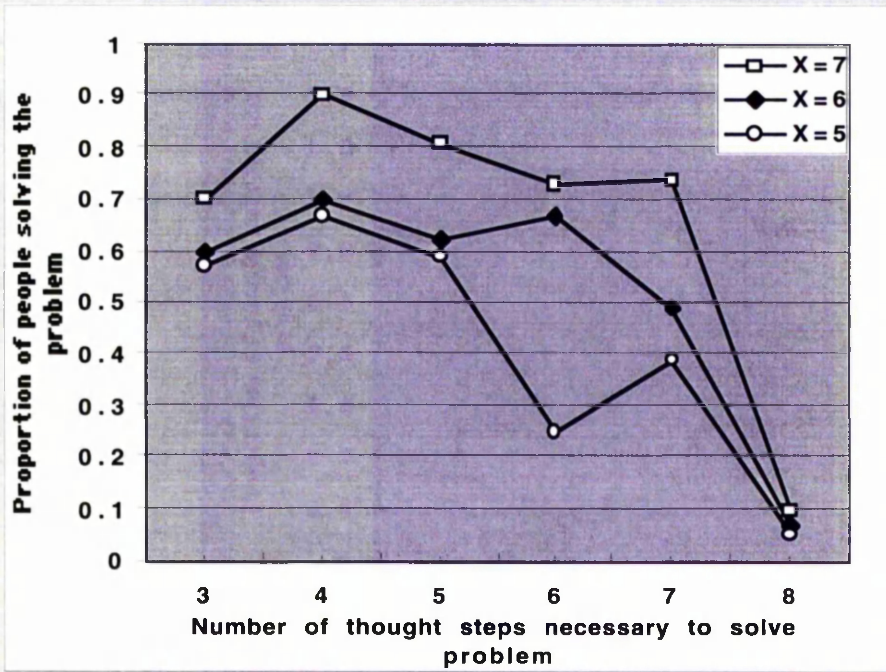
> i. *Because of its limited capacity, working memory can be easily overloaded (e.g. irrelevant information, difficult or unfamiliar vocabularies).*
> ii. *When working memory is overloaded new information cannot be received.*
> iii. *The processing of information cannot take place in an overloaded memory unless this information can be effectively chunked.*
> iv. *There is a relationship between the working memory capacity of the students and their performance in problem solving or other tests.*

Barber (1988) argued that "if the information we are concerned with reaches the upper limits of our working space, an overloading in the capacity of working memory could occur. A loss in productivity may arise."

An unfamiliar word in a text takes up valuable working space. When learning in second languages occurs, working memory is used not only for holding and processing but also for translating. This may need a lot of working space according to Selepeng (1995). Even a negative question demands more space than a positive one (Cassels and Johnstone, 1982). Johnstone and Wham (1982) showed that when the learner has difficulty in distinguishing the 'noise' from the 'signal', as we labelled this in previous paragraph, overload of working memory is likely to appear.

The relationship between working memory space and problem solving success has been examined several times by different researchers. Johnstone and El-Banna (1986) showed that, if the number of things the students are supposed to hold in mind at a time, in order to solve a problem, exceeds their working space capacity, then their performance will fall down. They measured the working memory capacities of 471 upper secondary school chemistry students and gave them chemistry problems to solve. These problems were analysed into the number of thought steps that an unsophisticated student would take in solving them. The 'number of thought steps' was the sum of units of information in the question, units to be recalled and processing steps. The fraction answering each question correctly was plotted against the number of thought steps required, using different curves for students with working memory capacity five, six or seven and they came out with the results shown in Figure 2.3.

Figure 2.3 The fall-off in proportion of students solving problems when the number of thought steps required exceeds a student's working memory space capacity



Johnstone and El-Banna, (1986)

The results show that when the number of thought steps required exceeds the student's working memory capacity, there is a marked fall-off in proportions of students solving the problem. This of course does not mean that a student with a small working memory capacity is not able to solve problems or incapable of learning. There are many different ways of using limited working space memory efficiently by developing strategies of chunking. This is also probably the reason why performance does not fall to zero however large is the information given. This research examines this hypothesis in the context of algebra story problems in the fifth chapter.

2.3.5 Long Term Memory

Long term memory is, according to Johnstone *et al.* (1994), a large store, where facts are kept, concepts are developed and attitudes are formed. It is the ultimate destination for information a person wants to learn and remember, the memory system responsible for storing information on a relatively permanent basis (Ashcraft, 1994). Long term memory is a permanent repository of information that we accumulate over periods of days, weeks, months and years (Brunning *et al.*, 1995). Although forgetting occurs, there is a debate whether it happens because metabolic changes cause gradual decay or because of the inability to retrieve from the memory. According to Solso (1995), the capacity of long term memory seems to be limitless, and its duration virtually endless.

There is more than one distinction of the long term memory in the literature: Tulving (1986) argued that long term memory consists of two components: *episodic* and *semantic* memory. Episodic memory supposed to be an individual's autobiographical record of previous experience (memories, feelings etc.). On the other hand, semantic memory is the memory for meanings, which includes language, rules, and concepts. Another long term memory distinction is that of Anderson (1982) and Squire (1987), who introduced the *declarative* and the *procedural* long term memory. According to them, declarative memory holds 'knowing of what', such as meaning of words, description of facts, recalling names of the capital of countries and generally what is in our consciousness. Procedural long term memory holds 'knowing how', such as how to drive, walk, talk and generally how to perform certain activities.

According to Johnstone's (1993a) Information Processing Model, the long term memory is linked with the perception filter and the working memory and affects the way these function and the way the information is processed. What is available in long term memory is very important because it may distort the selection process and provide, for the working memory, information which is incompatible with what is coming in from outside (Driver *et al.*, 1985). Consequently it is very important to examine the ways the information is stored in the long term memory.

The information stored in the long term memory is information potentially important, interesting, or useful for every individual. Irrelevant or unimportant information is ignored. This process is totally personal and memory uses a variety of functions such us: pattern recognition, rehearsal, elaboration, organisation. Memory is functioning constructively using something like a 'make sense-does not make sense' filter.

Johnstone (1997) suggested four ways of storing:

> *i. The new knowledge finds a good fit to existing knowledge and is merged to enrich the existing knowledge and understanding (correctly filed).*
> *ii. The new knowledge seems to find a good fit (or at least a reasonable fit) with existing knowledge and is attached and stored, but is in fact, a misfit (a misfiling).*
> *iii. Storage can often have a linear sequence built into it, and that may be the sequence in which things were taught.*
> *iv. The last type of memorisation is that which occurs when the learner can find no connection which to attach the new knowledge.*

The first way of storing is linked to the meaningful learning whereas rote learning occurs in the last way of storing. Johnstone called the first type of storing 'correct filing' because this memorisation is very easy to retrieve and almost never lost. On the other hand, rote memorisation is very likely to be lost and very difficult to retrieve. Linear memorisation is when something is memorised like the alphabet and can be assessed in only one way except if it can be broken down by branches, as Reisberg (1997) suggested, which makes the access and retrieval easier.

2.4 Cognitive Styles

Individuals are always exposed to information coming from the environment. Information that needs to be received, processed and responded to. Every individual has his/her own way of perceiving, selecting and processing that information, depending upon what they already know (like their beliefs, prejudices).

These differences in cognitive structure and in psychological functioning constitute the different cognitive styles of the individuals, or, as Witkin (1974) labels it, 'psychological individuality'. According to Cross (1976), each individual has his own style for collecting and organising information into beneficial knowledge. For instance there are students who feel more comfortable with manipulating abstract materials, while others prefer concrete ones.

There are students, especially in mathematics, who prefer geometry because they find it easier to visualise and they solve the problems by drawing shapes, in contrast to algebra, which is more symbolic. According to Sharma (1989) each one of us has a unique mathematics learning personality. There are individuals who are very sequential in their approach to learning mathematics and these are called by some researchers (like Krutetskii, 1976) 'algebraic type'. On the other hand, individuals that process information visually, holistically, are called 'geometric type'. Sharma (1989) has analysed further the different mathematics personalities which arises from the differences of the individual's processing of information.

Saracko (1997) argued that cognitive styles identify the ways individuals react to different situations and they include stable attitudes, preferences, or habitual strategies that distinguish the individual styles of perceiving, remembering, thinking and problem solving. Cognitive styles have nothing to do with intelligence or abilities. If it could be assumed that our sensor receivers, memory etc. are the organs we use to interact with our environment, cognitive styles refers to how effectively we use these organs. The focus of this research is a specific kind of learning styles the field dependence/independence. This is now discussed.

2.4.1 Field-Dependence/Field-Independence

The ability to distinguish between important and unimportant information within a flow of information is called field-dependence/field-independence cognitive style. The field-dependence/field-independence cognitive style theory originated in Witkin's work (Witkin, 1974, 1977; Witkin *et al.*, 1977; Witkin & Goodenough, 1981). According to Witkin & Goodenough (1981), a field-dependent (F.D) individual is someone who has difficulty in separating an item from its context. On the other hand, a field-independent (F.IND) individual is someone who can easily break up an organised field and separate relevant material from its context, that is distinguish between the *signal* and the *noise.*

In order to measure the field-dependence/field-independence of an individual, Witkin *et al.* (1977) used the 'group embedded figures test' (GEFT). It is a paper-and-pencil test where the subjects are asked to recognise and identify a simple geometrical shape within a complex pattern. The more correctly they identify shapes, the better the subject is at this process of separation and is called field-independent person, and vice versa for field-dependent. Subjects with middle performance are called field-intermediate (F.INT).

2.4.2 F.D/F.IND and Working Memory Space Capacity

Many researchers have investigated the relationship between field-dependence/field-independence and working memory capacity. Pascual-Leone (1970), Case (1974), Case & Globerson (1974) argued that there are differences in the way field-dependent/field-independent subjects are using their working memory. The results of a number of studies (e.g. Pascual-Leone, 1970; Berger, 1977; El-Banna, 1987; Al-Naeme, 1988, 1991; Ziane, 1990) have shown that the larger the working memory capacity of the subject, the more likely for the person to be field independent. El-Banna (1987) examined the relationship between performance in chemistry examinations of low, medium, and high working memory capacity students and field-dependence. He came out with results showing that among students with the same working memory capacity, the performance declines when the student is more field-dependent. A possible explanation for these results could be the fact that students with low working memory capacity are not in position to devote any working space to the irrelevant information, and consequently field-independent low working memory capacity students would possibly perform better than the field-dependent low working memory capacity.

Al-Naeme (1988) found little difference in performance in a chemistry examination between low working memory capacity field-independent students and high working memory capacity field-dependent students (Table 2.1).

Table 2.1: The overall performance for Students of different capacities and different degrees of F.D/F.IND in a chemistry examination.

WORKING MEMORY CAPACITY	MEAN SCORES %		
	F.D	F.INT	F.IND
LOW (N=77)	36.1	38.2	45.2
MIDDLE (N=62)	42.1	44.8	47.4
HIGH (N=90)	45.6	47.0	49.1

Al-Naeme, (1988)

Johnstone *et al.*(1993) suggested a possible explanation for these results. According to him, students with a high working memory space capacity and field-dependence are occupied with noise as well as with signal because of the field dependence characteristic. On the other hand, low capacity and field-dependent students will receive only the signal and ignore the noise and they can use all their limited low working memory space for useful processing. Therefore high capacity field-dependent students cannot benefit from their larger working memory because it is reduced by the presence of useless information.

As far as the relationship between field-dependence/field-independence and academic performance is concerned, much research (e.g. Witkin et al., 1977; MacDonald, 1984; El-Banna, 1987; Ziane, 1990; Johnstone & Al-Naeme, 1991; Uz-Zaman, 1996; Tinagero & Paramo, 1997; Danili, 2001) has found that field-independents score significantly higher than field-dependents in almost every field of science.

Based on this past research and their conclusions, this project investigates how the working memory capacity and the cognitive styles of the students influence their performance in a specific area of mathematics called 'representation of algebra story problems'. In the next chapter there is a brief introduction of the algebra story problems and the difficulties in representing them, and a literature review of the latest research in this area.

Chapter Three

Story Problem Difficulties
Applying the Information Processing Model

As part of the investigation of students' capability in applying mathematics in everyday life, their performance in dealing with representation of algebra story problems is considered in this research. In this chapter, after giving the definition of story problems, the difficulties and the major factors that affects success in problem representation are discussed, based on the international literature. Several possible factors for the students' difficulties have been identified from the literature: text comprehension, problem categorisation, working memory space capacity and the processing of information, cognitive style and attitude toward mathematics. Each one is discussed in turn.

3.1 Story Problems and Problem Solving

Story problems in algebra is a special category of problem solving in mathematics. Lawton's Dictionary of Education (1996) has defined problem solving as "a style of teaching and learning where the aim is to encourage the pupils to acquire knowledge and skills in the process of solving problems rather than simple learning about how others have solved such problems". There are many definitions of problem solving from many different authors. Two are chosen to show the importance of teaching and learning problem solving. According to Mayer (1997), problem solving is almost synonymous with thinking. Ausubel *et al.* (1978) defined it as a form of meaningful discovery learning, but not a completely autonomous discovery. He argues that no frequently practised procedure or strategy could be called problem solving. Problem solving is a type of learning in which problem conditions and desired objectives are substantially related to existing cognitive structures.

What makes problem solving so interesting as a teaching and learning tool is that it is different from doing exercises, even if exercises are the most usual form encountered in school books. The significant difference between "problems" and "exercises" is well defined in Johnstone's (1993) problem classification. He argued that there are three variables associated with all problems: the data provided, the method to be used and the goal to be reached. By looking at the extremes where each variable as either known or unknown, he came up with eight types of problems, shown below (Table 3.1).

Table 3.1: Classification of problems

Type	Data	Method	Goals/ Outcomes	Skills Bonus
1	Given	Familiar	Given	Recall of algorithms
2	Given	Unfamiliar	Given	Looking for parallels to known methods
3	Incomplete	Familiar	Given	Analysis of problem to decide what further data are required
4	Incomplete	Unfamiliar	Given	Weighing up possible methods and then deciding on data required
5	Given	Familiar	Open	Decision making about appropriate goals. Exploration of knowledge networks
6	Given	Unfamiliar	Open	Decisions about goals and choices of appropriate methods. Exploration of knowledge and technique networks
7	Incomplete	Familiar	Open	Once goals have been specified by the student, these data are seen to be incomplete
8	Incomplete	Unfamiliar	Open	Suggestion of goals and methods to get there; consequent need for additional data. All of the above skills

(Johnstone, 1993)

Type 1 is of an algorithmic nature, that is all three variables are familiar to the students, and is regarded as an 'exercise'. On the other hand, a 'problem' is what exists "whenever there is a gap between where you are now and where you want to be, and you don't know how to find a way to cross that gap" (Hayes, 1981). Consequently, as Blum, & Wiss (1991) argue, it depends on the student and his/her knowledge and experience whether a particular task is a problem or an exercise. Problem solving difficulties are of great concern in the literature of mathematics education. Research has specified a number of mental and psychological factors responsible for problem solving success.

3.2 Problem Representation Difficulties

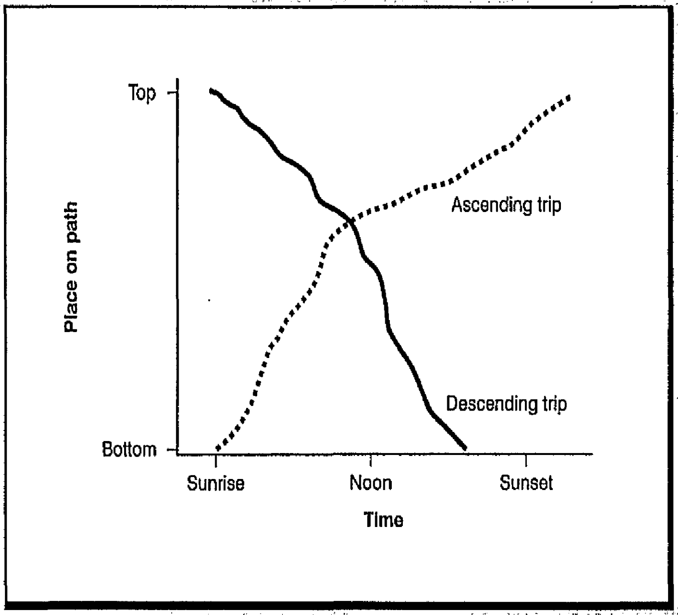
There is a consensus that mathematical problem solving can be broken down into two major parts: *problem representation*, which is converting a problem from words into an internal representation; and *problem solution*, where the legal operators of mathematics are applied to an internal representation in order to arrive at a final answer (Bobrow, 1968; Wickelgren, 1974; Hayes, 1981; Polson & Jeffris 1982, 1985; Mayer, 1983; Riley *et al.* 1983; Riley & Greeno, 1988; Dark & Benbow, 1990; Lucangeli, *et al.* 1998).

A problem can be represented in several ways. Abstractly thinking about the problem, without putting these thoughts on paper, is one way. Another way is by producing a tangible representation such as a graph, a table, a picture, or an equation. A tangible representation is very useful in helping the processing of information. Because of the limited capacity of short term memory, any form of external representation can reduce the amount of information that needs to be held.

In computation and also in solving problems, people first construct an internal representation (visual, spatial or motor) of the terms, numbers, and operations, and subsequently transform this internal representation into formal equations or other mathematical expressions (Larkin, 1977). There is a big debate about the characteristics of this mental representation. Some believe that it is in a propositional format and others in pictorial format. Probably this depends on the solver and the type of the problem and data given (Nathan *et al.* 1992). However, there is a consensus that visual representation plays an important role in the organisation of information given in the text and consequently on the comprehension of the problem and the solution plan (Wicker *et al.* 1978; Kaufman 1988, Lewis 1989; Antonietti 1991; Hegarty *et al.* 1995; Lucangeli *et al.* 1998). Sometimes, visual representation of a problem, can also lead to the solution much more easily that other strategies. Consider the Monk's Trip problem:

'A monk journeys all day on foot to the top of the mountain, meditates overnight, and then returns by foot again the following morning by way of the exact same path, making the return trip down the mountain in two-thirds of the time. Is there a spot on the trail that the monk crosses at exactly the same time each day?'

Figure 3.1: Graphic representation of the Monk's Trip problem



Hayes, (1978)

Solving the problem without making a picture would be much harder than solving it pictorially (see Figure 3.1). According to Brunning *et al.* (1995) one reason for this difficulty is that much of our limited capacity in short term memory is exhausted just trying to remember relevant information and few resources are left over to actually solve the problem.

Especially for the category of algebra story problems, other procedures are also required for a successful representation. According to Mayer (1985), algebra story problem representation involves *translation* of each sentence from real language into some other form, such as an equation, and *integration* of the relevant information into a coherent representation of the problem.

3.3 Problem Translation

Almost everyone agrees that translation of real language expressions into mathematical language and expressions (like formulas, equations, models) is the most important process involved in solving word problems. Students find difficulty in moving from a linguistic presentation of the problem to a numeric one, even if they are able to solve the same problem presented numerically. Translation skills are difficult because behind them there are many unarticulated mental processes that guide one in constructing a new equation on paper (Clement *et al.* 1981). There are many variables responsible for success in this task. Reading comprehension is believed to be one of these variables.

3.3.1 Reading Comprehension

Reading comprehension, is one of the main abilities which has a role in students' performance in solving story problems (Aiken, 1972; Mayer, 1984; Philips *et al.* 1983; Muth, 1984; Swanson *et al.* 1993). According to Kintsch and Greeno (1985), when encountering a word problem, students first need to make sense of the text of the problem. They argued that solving word problems is a two-step process. In the first step, the reader creates schemata (mental representation of a problem) in order to comprehend the text of the word problem. In the second step, these schemata activate mathematics schemata that lead to problem solution. In order to succeed in translation, students need some knowledge of both 'languages'; real language (like vocabulary, syntax) and mathematical language (like symbols, concepts). There are problems that are more difficult than others, and sometimes this is due to the way the problem is given to the students. The words, the syntax, the sentences that the problem consists of are important for the comprehension of the problem.

Mayer (1982b) suggested that part of the difficulty stems from the structure of the language used in the problem. According to his classification, in every word problem, the information relevant to the solution can be given by using four different kinds of propositions: *Assignment proposition*, which involves giving a single numerical value for one variable (for example: Tom is 50 years old); *relation proposition*, which involves giving a single numerical relationship between two variables (for example: John has three marbles more than Ann); *question proposition*, which involves the question asked in the problem (for example: what is the age of father ?); and *relevant fact*, which are sentences that gives information important for the integration of the problem (for example: they both use the same route). Research has suggested that students process differently the different kind of propositions in the problems.

Riley *et al.*, (1983) and Greeno, (1980) suggested that students may have more difficulties in representing relational propositions than other kind of propositions. A reason for that could be that it is more difficult to recall relational propositions. For example, children in primary grade where asked to listen to and immediately repeat problems involving relational propositions, such as: "Joe has three marbles. Tom has five more marbles than Joe. How many marbles does Tom have?" The children tended to make errors in repeating the relation, such as saying, "Joe has three marbles. Tom has five marbles. How many marbles does Tom have?" (Mayer, 1985).

Mayer (1982) asked the students to read and recall eight algebra story problems like the one that follows:

> *A river streamer travels 36 miles downstream in the same time that it travels 24 miles upstream. The steamer engines drive in still water at a rate of twelve miles per hour more than the rate of the current. Find the rate of the current.*

He found that students made approximately three times as many errors in recalling relational propositions (29% errors) than in recalling assignment propositions (9% errors). One factor believed to underlie the difficulty of representing relational expressions is the great storage requirements that they impose on the working memory system relative to simple assignment statements or questions (Kintsch & Greeno, 1985).

Clement *et al.* (1981) and Soloway *et al.* (1982), asked college students to write an equation to represent the following statement:

> *There are six times as many students as professors at this university.*

One third of the students got the problem wrong and produced an equation such as 6S=P. By interviewing the students, two distinct sources for the their tendency to reverse variables were identified. The first faulty approach was called 'word order matching' and is described by Paige and Simon, (1966) as 'syntactic translation'. This is due to direct mapping from the words of English to mathematical symbols. The second false approach of the problem is called 'static-comparison' method. The students understand that the sentence implies that the student population is bigger than the professors population. They are still using the equation 6S=P, because the expression '6S' is used to indicate the larger group and 'P' the smaller one. The letter P does not represent the number of professors, but stands for 'a professor', the letter S does not represent the number of students but stands for 'the students for that professor' and '=' stands for a static association between S and P and not a precise equivalence.

3.3.2 Compare Problems

The domain of arithmetic word problems can be analysed into several problem types, including "compare problems": problems concerning a static numerical relation between two variables (Mayer, 1981; Riley *et al.* 1983). *Consistent* and *inconsistent* language problems are two forms of compare problems. In consistent language problems, the unknown variable (e.g., Tom's marbles) is the subject of the second sentence, and the relational term in the second sentence (e.g., more than) is consistent with the necessary arithmetic operation (e.g., addition).

For example:

Joe has 3 marbles
Tom has 5 more marbles than Joe.
How many marbles does Tom have?

On the other hand, in inconsistent language, the unknown variable is the object of the second sentence, and the relational term (e.g., more than) conflicts with the necessary arithmetic operation (e.g., subtraction). For example:

Joe has 5 marbles
He has 3 marbles more than Tom.
How many marbles does Tom have?

(Lewis & Mayer, 1987).

Research results have indicated that inconsistent language problems are more likely to cause miscomprehension and errors (Hutterlocher & Strauss, 1968; Riley *et. al.* 1983; Lewis & Mayer, 1987).

Other factors that affect problem solving success are whether the problem contains just the information needed for the solution or contains also extraneous information. Problems using extraneous information are more difficult for students to solve. A reason for that could be that extraneous information is harder for students to remember according to Cooney's and Swanson's (1990) and Mayer's (1982) findings. In addition extraneous information produces confusion especially to poor problem solvers. Irrelevant information is an amount of information that is more likely to cause overloading of working memory space. It is due to the students' capability to distinguish between relevant and irrelevant information that affects success.

3.4 Problem Integration

Even if sometimes the sentence-by-sentence translation would lead to a correct representation, there are plenty of examples where it is impossible or just wrong to do so. For example Paige and Simon (1966), presented 'impossible' problems like the following:

The numbers of auarters a man has is seven times the number of dimes he has. The value of the dime exceed the value of the auarters bv two dollars and fiftv cents. How manv has he of each coin?

Even if it is possible to represent this problem, it would be wrong to do so. Thus problem representation is more than sentence by sentence translation: as well as translation, integration is also needed. Integration is the second step in Mayer's (1985) model and it is where propositions are put together into a coherent whole. Integration is significantly depended on knowledge of problem types, that is problem classification. This is now discussed.

3.4.1 Problem Schemata

Problem schemata are defined as the correct classification of problem types (Mayer, 1985; Lewis & Mayer, 1987). Problem schemata are considered to be an important source of problem solving accuracy (Briars & Larkin, 1984; Hinsley *et al.* 1977; Mayer, 1982, Lucangeli *et al.* 1998). Mayer (1981) analysed algebra story problems in a number of high school algebra textbooks and he found more than 100 problem types. The problems differed in frequency of appearance in textbooks. When he asked a number of students to read and then recall a series of eight story problems, they remembered high-frequency problems more successfully than low-frequency problems (Mayer, 1982). This finding suggests that students possess 'schemas' for problem types, and uses these schemas to mentally represent the problem, and when they lack a schema, the possibility of wrong representation increases.

In order to investigate the affect of schema development in problem solving accuracy, Silver (1981) asked seventh-graders to sort sixteen story problems into piles on the basis of similarity. Then he compared the sorting performance of the good and poor problem solvers. He found that good problem solvers were sorting the problems according to *deep structure* principles, such as what kind of solution strategy is required to solve the problem. On the other hand, poor problem solvers, tended to group the problems on the basis of the *surface structure* features, such as the objects that appear in the problem. Hardiman *et al.* (1989) agree with these results.

These findings would normally have suggested that, in order to eliminate wrong representations in word problems, students should try to develop and store as many schemata (meaning mental representation of the problem here) as the varieties of problems that exist within a cluster. Considering the fact that there are plenty of subtypes of algebra problems that would need a new schema to be developed, something like that would just be impossible to happen. In any case that would not help a lot, because there is also an other point of view in the way problem schemata are functioning.

Reed's (1984) work on algebra errors suggests that, sometimes, students' errors in algebra are caused by wrong manipulation of problem schemata. A wrong identification of a problem would lead to a wrong solution. Student's problem schemata often are incompletely understood or stored so specifically that they are not perceived as useful for solving other problems. Slightly different problems are very often solved in exactly the same way by students, and that can lead to mistakes. These findings suggest that algebra instruction produces rote acquisition of schemata. Such schemata cannot be applied to problems even when these are slightly different from those on which the schemata were based. This is another indication of the difficulty in reducing errors in algebra word problem solving.

Apart from the significant correlation between problem schemata and achievement in problem representation, problem schemata seems to help in making inferences about what is remembered from a story problem (Mayer, 1982), and also the relevance of information contained in word problems and elimination of extraneous information (Briars & Larkin, 1984; Kintsch & Greeno1985).

3.5 The Influence of Working Memory

When a story problem is given to students, an amount of information is given to them. In order to represent this problem in another form, information-processing procedures are taking place. According to the Information Processing model already discussed in the previous chapter, working memory space capacity would be an important variable that affects success. Most of the research that has taken place in this field has demonstrated a big correlation between working memory space and performance in representing algebra story problems.

Working memory space is of major importance in mathematical story problems procedures, and is possibly responsible for differences in student's problem solving performance (Hitch, 1978; Brainerd & Reyna, 1988). There are different approaches in the way working memory influences the information process. Just and Carpenter (1987) argued that many processes operate in a parallel way and that working memory is used as a common work space, where processes can place partial and final results. As far as reading comprehension is taking place, Kintsch and van Dijk (1978) proposed that working memory is used to keep active a number of text propositions in order to get them integrated. In the same direction, Kintsch and Greeno (1985), refer to working memory as an important variable affect comprehending text propositions (like relational, assignment and question propositions), and succeeding in problem representation.

Working memory space influences the factors we have already mentioned as significant for accuracy in problem solving like the processing of language, different propositions and extraneous information. High correlation between working memory scores and problem classification (Mayer, 1982; Cooney & Swanson, 1990, Swanson et al. 1993), also support the assertion by Kintsch and Greeno (1985) that knowledge structures and elementary information processing operations are related. Thus, working memory is also correlated with the ability to make inferences about the relevant and irrelevant information to the solution, which lends support to the schema hypothesis.

Most of the research in the cognitive literature assumes that there is a big correlation between working memory space and general mathematical ability (Chiang & Atkinson, 1976; Dempster & Cooney, 1982). Even when Swanson *et al* (1993), found weak correlation between memory and problem solving success, working memory and classification ability were significant predictors when students are forced into the equation first. According to research carried out by Kourkoulos (1996) which used 350 Greek students (15-16 years old), a reason for incorrect representation of story problems was that students did not use all of the information given. The equations that the students produced were not completed. This is possibly a working memory capacity problem.

3.6 Applying the Information Processing Model to Algebra Story Problems

This section is an attempt to bring together all the previous factors that influence achievement in algebra story problems representation, as the literature has indicated, into a model. Models sometimes help in synthesising things to create a picture where it is easier to observe how different factors affect each other and which are the processes that lead to any possible outcome. The Information Processing Model (Figure 2.2) will be used as the basic structure of this model.

When a word problem is given to students in real language, this information is receives by their senses: they read or listen to the problem. This information, goes through the perceptive filter. Some of this information is immediately rejected because it is irrelevant according to problem schemata already held. The problem schemata are cognitive structures held by everyone in long term memory, created from previous experiences in problem solving and stored there in a specific and personal way. Because of the feedback loop between long term memory and perception filter, these previous structures affect what someone think is important and what is not important from the given information. The important information then goes to the working memory space.

In the working memory space, many processes take place at the same time. Firstly, working memory space is responsible for holding the information. Words, propositions, values, relations and so on occupy some space in the working memory space. Apart from just holding, working memory space is responsible for working on that data. Working memory is directly connected to long term memory where all previous knowledge exists in structures, like language and the way it functions, mathematics, emotions, memories and so on. All the evidence lead to the conclusion that it is in working memory space where the problems are solved. Text comprehension is a procedure where we hold the information in the working memory, retrieve interpretation of vocabulary, syntax and symbols from long term memory and this way we come to understand and give meaning to what we have just read.

In addition to the text comprehension, the values and the questions are also held in the working memory space. There we retrieve mathematics schemata from the long term memory and apply it in these conditions in order to build the equation that represents the given statements. We throw away things that are not important and we can always use our senses to take new data from the environment (like to read the instructions again, find helpful text books, look for similar problems). By holding and processing all the information given and the ones we already have in the long term memory, we create a holistic representation of the problem which then takes mathematical form to give the equation requested. Finally the working memory space is responsible for storing in the long term memory the new experience taken from the solving of every problem.

In these processes many things are likely to produce overload of working memory space, like difficult vocabulary, different kind of propositions, extraneous information or negative questions. On the other hand, a problematic storing or retrieving from the long term memory could lead to incorrect outcomes. Problematic retrieving could be caused due to many reasons. Previous incorrect storing or retrieving of the wrong structure could be some of the reasons.

The above general picture is examined in this research in chapter five. Moreover, before that, it important to give a brief presentation of another possible factor that affects achievement in mathematics: the students' attitudes towards mathematics.

3.7 Attitudes Toward Mathematics and Achievement

According to Mayer (1982), it is impossible to separate the cognitive from the affective domains in any activity. Attitudes, beliefs and emotions are the major descriptors of the affective domain in mathematics education (McLeod, 1992), whereas knowledge and thinking are considered descriptors of the content and process of the human mind (Brown & Borko, 1992).

There are many definitions of 'attitude'. Aiken (1970a), defined it as "a learned predisposition or tendency on the part of an individual to respond positively or negatively to some object, situation, concept, or another person". Neal (1969) referred to attitude as an aggregated measure of "a liking and disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless". In Ma's (1997) meta-analysis of the relationship between attitude toward mathematics (ATM) and achievement in mathematics (AIM), Neal's definition is extended to include students' affective responses to the easy/difficult as well as to the 'importance/unimportance' of mathematics.

The mathematics attitudes included for study, according to Fennema and Sherman Mathematics Attitudes Scales (FS-MAS) (1976) are: (a) mathematics confidence; (b) extrinsic mathematics motivation - described as the desire to achieve mathematics awards and recognition; (c) mathematics as a male domain - described as 'mathematics is a gender neutral subject'; (d) mathematics usefulness; and (e) intrinsic motivation to study mathematics - described as 'personal enjoyment' and 'pleasure in the study of mathematics'. The relationship between attitude toward mathematics (ATM) and achievement in mathematics (AIM) is of great concern in the literature of mathematics education.

"Teachers and other mathematics educators generally believe that children learn more effectively when they are interested in what they learn and that they will achieve better in mathematics if they like mathematics. Therefore, continual attention should be directed towards creating, developing, maintaining and reinforcing positive attitudes" (Suydam and Weaver, 1975). The way attitudes influence performance in a mathematics task is examined in this research. Even if the relationship between ATM and AIM has long been assumed from mathematics educators, little consensus exists in the literature. That is perhaps because of the multifaceted nature of what is called attitudes which includes the range from attitudes toward the teacher and the whole educational system to attitudes towards the mathematical symbols and so on as well as the method used by each researcher in order to 'measure' attitudes. Students' attitudes towards a discipline is not something that can be marked and easily put on scale.
A number of researchers have demonstrated that the correlation between ATM and AIM

is of low significance, ranging from zero to 0.25 in absolute value, and that ATM accounts for, at best 15% of the variance in AIM (Abrego, 1966; Wolf & Blixt, 1981). According to them, the relationship is very weak and has no useful indication for educational practice.

On the other hand, Enemark and Wise (1981) argued that "the attitudinal variables are significant indicators of mathematics achievement". According to Steinkamp (1982), one of the variables that determine AIM is ATM. Sherman (1980), Minato (1983), Minato, & Yanase (1984), Ethington & Wolfle (1986), Lester *et al.* (1989), Marshall (1989) demonstrated that the correlation between ATM and AIM is above 0.4 and so ATM plays an important role in explaining AIM.

Other findings in this area show that, even if the relationship between ATM and AIM is statistically significant (correlations ranging from 0.20 to 0.40 in absolute values, which is the most usual finding), it is not very strong from a practical perspective (Anttonen, 1968; Jacobs, 1974; Quinn, 1978). Consequently, the relationship between ATM and AIM is either not significant, according to the literature review of Robinson (1975), as mentioned in Ma's (1997) meta-analysis, or significant but not strong according to Aiken, (1970a, 1976) and Neal, (1969). Correlation does not imply causality. It is not possible to be sure which variable is the cause and which the effect. So even strong correlation values alone mean nothing without a underpinning theory.

As far as gender differences in mathematics performance are concerned, again little consensus exists in the research literature. Gender differences in mathematics achievement and skills are either very small or declining as the society grows according to Friedman (1989), Frost *et al.* (1994), and Hyde *et al.* (1990). Ma's (1997) meta-analysis demonstrates that gender differences in the relationship between ATM and AIM are also very weak. On the other hand, Aiken's (1970a, 1976) literature review found gender differences in the ATM and AIM relationship, and Philips *et al.* (1983) argue that males are significantly better than females at solving word problems in algebra, and that males have more positive attitudes towards mathematics than females, even if attitude is not a major contributor factor in the ability to solve word problems in algebra.

Family, school type, region and ethnicity are other factors that the literature has tried to investigate in relation to mathematical achievement (Ma, 1997a). The influence of family on students' achievement has been recognised by many researchers (Anyon, 1983; Theisen *et al.*, 1983; Eccles *et al.*, 1985; Fennema & Peterson, 1985; Fuller and Heyneman, 1989). The educational level of the mother and the father also seems to influence students' motivation and achievement in mathematics. School types play a role in achievement at mathematics according to Coleman *et al.* (1982), Hoffer *et al.* (1985), and Lee and Bryk, (1988).

The factors that affect achievement in mathematics and especially in representing mathematical problems are many. Apart from the cognitive and ability domain, social factors may be very important. That includes the very close environment of family, or school, social class, financial condition of the students' family, educational system and the way it is functioning, the teachers' level of education and experience and attitudes toward mathematics, their relationship with the students in the classroom, students' motivation for future career or study and many more factors affect the students' attitudes and achievement in mathematics. Some of these variables we are in position to understand and measure but there are possibly other factors we may not even begin to imagine that are significant in explaining students' achievement in mathematics.

Chapter Four

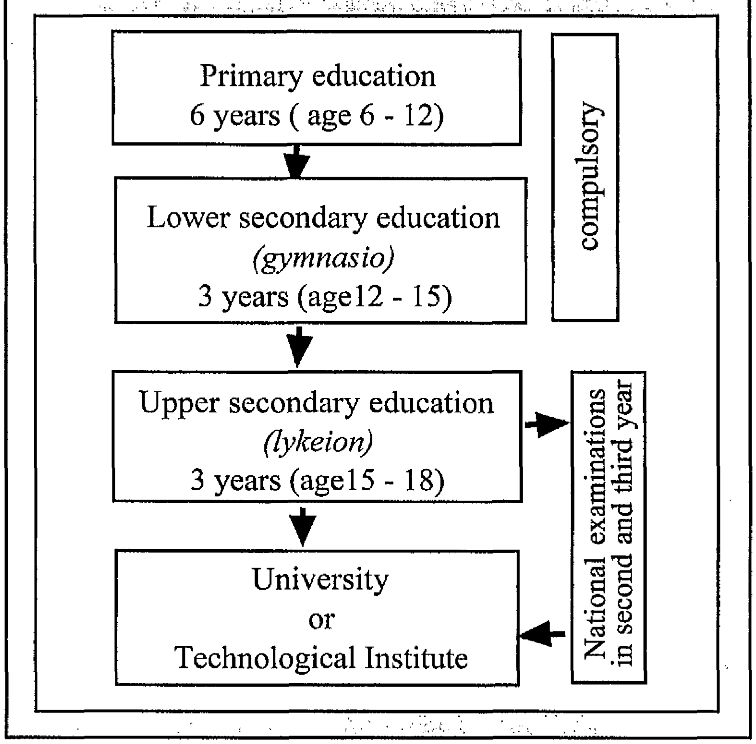
The Greek Education System

In this chapter, some information is given about the way the Greek education system is functioning, in order to become familiar with the educational environment from which the sample of this research comes. There is going to be a brief introduction to the structure of the education system and an analysis of specific problems that may influence the teaching and learning activity. The state of mathematics in this education system, problems and difficulties are discussed at the end of the chapter.

4.1 The Structure of the Greek Education System

The Greek education system requires 9 years of compulsory education. Six years of primary education (age 6-12) and three years of lower secondary education (*gymnasio* age 12-15). There are no national examinations for entering the upper secondary education (*lykeio* age 15-18) and the majority of the pupils attend upper secondary education (see figure 4.1).

Figure 4.1: The Greek education system



In the second and third year of lykeio the pupils participate in national examinations, in 9 subjects each time, in order to achieve the "National Leaving Certificate". Entering the higher education system (University or Higher Technological Institute) depends on the marks in National Leaving Certificate. These 9 subjects consists of main core educational subjects and subjects of interest known as 'direction of studies', that the students are free to choose. There are three directions of studies in the second and third year of lykeio: 'direction of science', 'theoretical direction' including subjects like history, Latin, classical Greek language, and 'technological direction'.

The curriculum and the teaching materials are introduced by the Greek Educational Institute and the Ministry of Education and Religious Affairs, and they are the same for all the schools in the country. All schools are mixed gender and there are no ethnicity differences. The majority of the students attends public schools, especially in the country side: consequently the schools contain pupils from all social classes.

4.2 Weaknesses of the Greek Education System

One of the main problems in the structure of the education systems is the examination system, which influences the whole teaching and learning activity especially in lykeio. The national examination at the end of the second and third year of high school are very important for every student. According to European Union research in the educational level of European countries, Greece has the third place in percentage terms of students attending higher education. 'Higher' (that is after high school technological institutes) and 'highest' (university) educational institutes in Greece are not connected to each other, which means that the only way to enter the university is to succeed in these examinations. Thus, the students are forced to make serious decision at an early age. This has also an effect on the way the lykeio is functioning. A big debate has been launched about whether the lykeio is an institute that provides knowledge in many different disciplines preparing students to become the future citizens, or just a preparation stage for entering the university.

The last three years of high school are no longer functioning as an autonomous higher level of general education. They are rather a *frontistirio* (a preparatory private institute that is, which offers support lessons to students to prepare them for the university) where the actual knowledge and deeper development of the teenagers are of minor importance, whereas what counts the most is a standardised and unfinished knowledge, 'a preserved education', which aims only to the pursuit of the grade. The final examination is what matters the most (Babiniotis, 2000).

Because of very strong competition and the difficulty of the national examinations, most of the students take support classes in frontistirio or private lessons at home. Many students start support classes even from the end of primary school and, in the last two years of lykeio it is unlikely not to do so. The average hours the students in lykeio, spend in support classes is 15-20 hours per week. Considering the fact that foreign languages lessons or music lessons are not included in this number, it is easy to deduce that high school students in Greece do not have much free time.

Another effect of the pressure of the national examinations is the way the students 'learn'. The students, in order to achieve greater marks, especially in the theoretical classes such as history and ancient Greek or even theory of physics and chemistry, are trying to learn by heart as many things from the text book as possible, so that they write it down as accurately as they can. This verbatim recall has nothing to do with a learning procedure but it is more like a device that helps examination success.

It is also very common for the students not to pay any attention to classes that are not in their direction of studies, neither on the main core, even from the first year of high school, in order to save time for their concentration subjects. For instance, it is very typical for a student who is interested in sciences to have less commitment in language or history classes.

However, the examination system and its effects are not the only problem in the education in Greece. Schools, most of the time, do not have basic teaching equipment such as computer laboratories, science laboratories, reading rooms, libraries and so on. The average number of pupils in the class is thirty, and this causes many problems in the teaching activity. Teachers in secondary education do not have any teaching training when they enter the classroom. Only in the last few years has the ministry of education tried to create a modern environment in schools, using technological equipment and laboratories in the teaching and learning procedure.

The way the education system is functioning influences the way mathematics is taught and the way learning takes place as well as the students' attitude toward mathematics. It is now useful to take a look at the feature of mathematics education in the Greek education system.

4.3 Mathematics in the Greek Education System

Mathematics is at the centre of Greek education. At all levels of education, teaching mathematics occupies considerable time: 4-5 hours per week in gymnasio, 5 hours per week in the first year of high school, and 2-7 in the second and third year, depending on the direction of studies chosen. The majority of the students make their decision about the direction of studies according to whether they prefer attending mathematical courses or not. Consequently, participation in mathematical classes is, indirectly, affected by students' achievement and their attitudes toward mathematics.

Because of its great value on the national examinations, achieving good marks in mathematics is very important for all the students. This affects the way mathematics is taught in the public or the preparatory schools. The teacher in high school "instead of teaching mathematics, is teaching the way of succeeding in examinations...mathematical work in the classroom focus on general prescriptions of doing exercises" (Adda, (1988) translated from Greek). The questions in the national examinations in mathematics are always exercises and never problems (Oikonomou, 1997), in the way we have already distinguished these two different types of mathematical aspects in a previous chapter. Considering the fact that in lykeio, it does not matter what you learn but what you take examinations in (Mpampiniotis 2000), problems in mathematics are not very usual in the classroom, especially in high school. This is maybe the reason for the high failure of the students in this area of mathematics, as shown by research in the Greek high schools carried out by Kourkoulos, (1996) and Hasapis (1993).

The way story problems are taught differs in every level of Greek education. Word problems are used extensively in primary school in order to make the pupils familiar with mathematical calculation and the mathematical problem solving logic. Word problems at that level are solved using verbal description of the solution and calculations in order to achieve the final solution. During secondary education, the unknown variable x, equations and systems of equations are introduced to the students. Thus, especially in the second and third year of gymansio, the way of dealing with solving problems is different. The students do not solve word problems by describing the solution. However they are forced to write down the right equation, by using symbols and mathematical concepts, and then solve this equation. In that way, word problems become representation problems.

The Greek students' capability in representing algebra story problems is being investigated in the next chapter. A sample of lykeio Greek students have been used in order to identify the mental and other factors that play role in problem representation difficulties. In the following chapter the way this research was carried out is discussed.

Chapter Five

The Influence of Cognitive Factors in Algebra Story Problems Representation

In this chapter, the way this project was carried out, the research method and the analytical tools is discussed. There is a brief presentation of the sample used, the test materials, and the method of analysis of the first stage of the research.

5.1 Sample Characteristics

This project was carried out in a town in Greece called Trikala. The students of a private support school were used. 90 students were involved; 49 of whom were girls and 41 boys. All of them were lykeio students, 15 to17 years old.

The reasons why a private support school (frontistirio) was chosen is that it is easier to gain access to the classroom of a private support school than the public school. The most important reason for that is that there are major bureaucratic procedures to get permission to do research in the public school. There are at least 30 students per classroom in the public school classroom which makes it very difficult for the research materials to be organised with the time and to fulfil all the proper conditions for accuracy (like proper instructions for everyone, no cheating, silence).

Almost everybody attends private school classes in private support schools. Consequently, the sample contains all kind of students, from good students who take classes for better preparation for the national examinations, to not so good students who take classes for school support. Students from different schools and from villages around gather in the same support school, which means that the sample covers a broad area of social classes. Private schools also cover all different disciplines of education.

Representation of algebra story problems is taught in the Greek education system during the last two years of gymnasio. It was chosen to work with students of all the three years of lykeio (age 15-17) in order to test their general ability in applying this knowledge that they are supposed to have. During lykeio, the level of the mathematics curriculum is much higher than representing algebra story problems. This knowledge is supposed to be a prerequisite of all the rest that will follow. Nonetheless, students appear to have many problems in this area of mathematics.

5.2 Methodology of the Research

The project was carried out in two stages:

First Stage:

- *Aim:* *To investigate the level of influence of certain psychological factors in performance in a specific mathematics tests.*
- *Method:*
    - *Measurement of psychological factors that influence the learning process.*
    - *Measurement of achievement in a specific mathematics test.*
    - *Analysis of the influence of these psychological factors to achievement.*

Second Stage:

- *Aim:* *To investigate what other factors like attitudes towards mathematics, social state of the student and his/her family etc, have a role in achievement in mathematics.*
- *Method:*
    - *Collecting information through a questionnaire.*
    - *Analysis of the influence of each factor coming out of a question in the questionnaire on achievement.*

5.3 Methodology of the First Stage

In this stage two psychological factors were measured for every student of the sample: working memory space and field-dependence(F.D)/field-independence(F.IND). A mathematics test was given to the students afterwards. The results of these tests were brought together and the way one factor is related to the other was analysed.

5.4 Measurement of Working Memory Space

To measure an individual's working memory space capacity, the Digit Backwards Test (D.B.T.) was used. There is a brief reference to the way this test works in chapter two (page 18). It consists of a set of digits, which are read to the students, who were asked to recall and write them down in reverse order, i.e. the set 5 8 4 9 should return as 9 4 8 5. Two series of the same number of digits were given and this number was increased by one, until 8 digits. Every digit was read to the students in a rate of one digit per second and the same time was given to recall after the reading of the whole series was over. The students were not permited merely to write backwards. Before the D.B.T. took place, the students were asked to do some examples of the Digit Span Test (in which they had to recall and write down the digits in the same order as they had heard it), in order to be sure that everyone understood perfectly the instructions given. This test measures students' memory capacity not only for holding but also for processing the information. The form of the test is shown in Appendix C.

The highest number of digits that a students was able to recall correctly in reverse order was considered to be the size of his/her working memory space capacity. Marking this test was done in the following way. When the subjects failed to recall both series with the same number of digits, then the previous level was taken as the mark that represents his/her working memory capacity. Figure 5.1 is an example of a student who was classified to have a working memory space equal to 6 because he/she was successful until level 6 but he/she failed in both attempts at level 7.

Figure 5.1: An example of marking a student's responses in the Digit Backwards Test

SET	NUMBERS							
2	4	2						V
	8	5						V
3	9	2	6					V
	5	1	4					V
4	9	7	2	3				V
	8	6	9	4				V
5	6	8	2	5	1			V
	3	4	8	1	6			V
6	8	1	4	3	1	5		—
	6	5	8	4	2	7		V
7	3	5	6	7	8	4	7	—
	8	2	1	4	9	4	7	—

Students of the sample were divided into three categories namely: *low*, *intermediate* and *high working memory space* capacity. Students who recalled correctly up to 5 digits (shown as X=5) were classified as *low working memory space*. Students who recalled correctly up to 6 digits were classified as *intermediate working memory space* (shown as X=6) and the rest who recalled correctly 7 or more digits, were classified as *high working memory space* (shown as X=7). The number of students in each category is shown in the Table 5.1. These results cannot be taken as 100% accurate on account of the fact that only one test was used, the symbolic one. For more valid measurement of the working memory space, two tests can be used, one symbolic and one visual and the values are taken after a comparison between the two tests. However time did not allow the use of both tests. For that reason the values of working memory space obtained from this test must be treated with caution. They are to be seen in a relative sense.

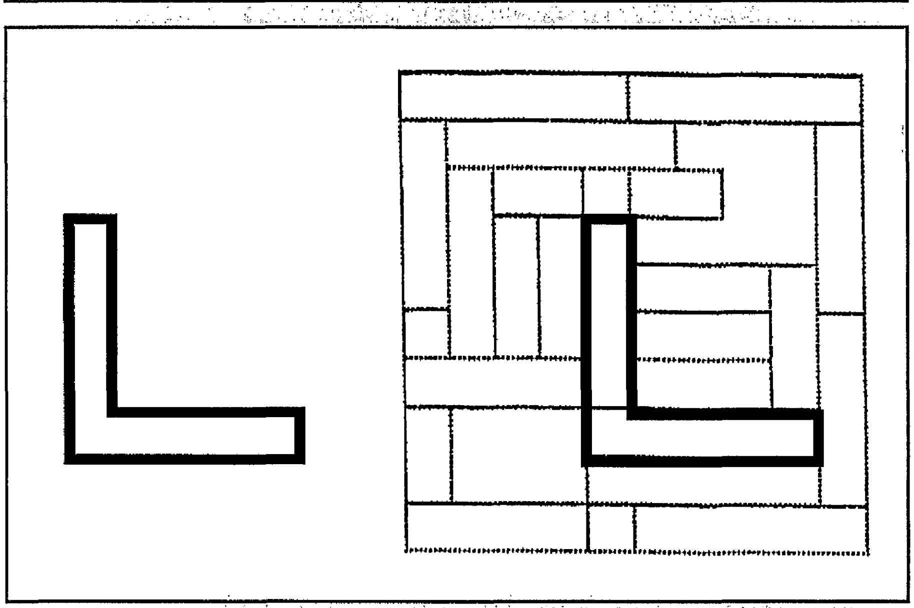
Table 5.1: The classification of the students into working memory space capacity groups

GROUP (X-Space)	NUMBER OF PUPILS
X=5	51
X=6	20
X=7	19
TOTAL	90

5.5 Measurement of Field-Dependence/Field-Independence

In order to measure the individual's degree of field-dependence, the Hidden Figure Test (H.F.T) was used. H.F.T. is a modified version of Witkin's *et al.* (1977) group embedded figures. In every task, the students were asked to recognise and identify a specific simple geometric shape (like the one shown on the left-hand side of the Figure 5.2) in a complex figure (like the one shown in the right-hand side of Figure 5.2), by tracing its outline with a pen or a pencil. The whole test consists of 20 tasks likes that.

Figure 5.2: Example of the Hidden Figure Test



The simple geometric shapes were gathered on the last page of the leaflet and the students were asked to remove it and have it always near them. There were also two examples that the students did first in order to make sure that everybody understood what they were asked to do. The sum of the correct answers was the score of the field-dependence of the subject. Thus the possible maximum score that can be obtained is 20. The H.F.T. and the answer to the tasks is presented in appendix F.

The instructions given to the students were as follows:

i. You can refer to the page of simple shapes as often as necessary

ii. 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,*

iii. Within each pattern, the shape you have to find appears only once. Trace the required shape and only that shape for each problem.

iv. Do the problems in order - do not skip one unless you are absolutely stuck.

v. You have 20 minutes to complete the whole test.

5.5.1 Classification of the Students into F.D/F.IND Categories.

In order to classify the students of the sample into Learning style categories, the same method used by a number of researchers (Al-Naeme, 1991; Danili, 2001) was used. According to this approach, field-dependent (F.D) students are considered to be those who scored less than a half standard deviation below the mean score. These who scored more than a half standard deviation above the mean score were considered to be field-independent (F.IND). The other students who scored somewhere in between were considered to be field-intermediate (F.INT) (see Appendix A-2).

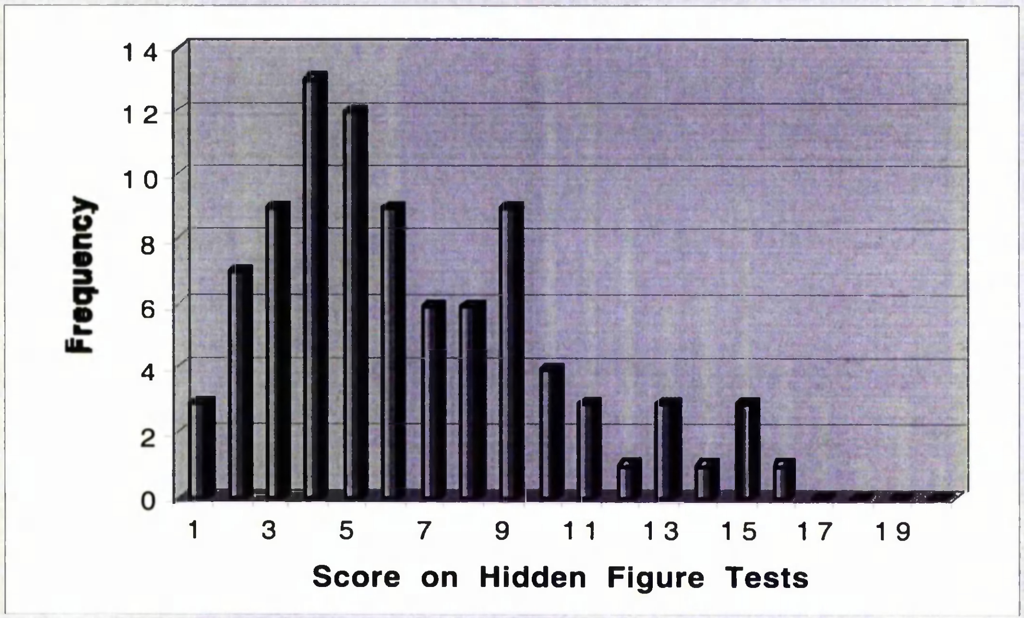
According to the above formula, the pupils were classified in three learning style categories according to their scores. Thus, those who scored less than 4.6 (which includes the scores: 0,1,2,3,4,) were considered to be F.D. Those who scored between 4.6 and 8.2 (which include the scores: 5,6,7,8) were labelled F.INT and the rest who scored more than 8.2 (scores: 9,10,11,...,20) were considered to be F.IND. The number of students in each learning style category is shown in Table 5.2.

Table 5.2: The classification of the students into F.D/F.IND learning style groups

GROUP	NUMBER OF PUPILS
Field-Dependent	32
Field-Intermediate	33
Field-Independent	25
Total	90

From the analysis of the data of the sample of 90 Greek students who completed the H.F.T it was found that the mean score was 6.4 and the standard deviation 3.6. The distribution of the H.F.T scores of the pupils in this sample is shown in the Figure 5.3.

Figure 5.3: Distribution of the F.D/F.IND total scores (Mean= 6.4, S.D= 3.6)



5.6 The Mathematics Test

In order to examine the students' capability in problem representation, a test with algebra story problems was given to them. This test consisted of ten story problems given in Greek language. The kind of the problems used were *compare problems* (that is problems concerning a static numeric relation between two variables), in Mayer's (1987) classification (see page 31). The students were asked to:

- name the variables they are going to use and
- write down the equation that represents the given statement

The problems used in the mathematics test were a mixture of statements from previous studies (Clement *et al.* 1980; Drak & Benbow, 1990; Lewis & Mayer, 1987), from the Greek Mathematics Textbook from the second year of gymnasio, and statements that were generated for the use of this research (Figure 5.4 presents the problems of the mathematics test, the full lay out as it was given to the students is presented in Appendix D). Based on previous research in this field, which is presented in chapter three, and according to the theories of the Information Processing Model the way the problems are given to the students is very important for the students to understand and succeed in solving them. As far as the language used, difficult vocabulary or syntax of the text is more likely to produce overloading of the working memory space.

Figure 5.4: The problems used in the mathematics test

Problem 1:

If Tasos raises 30p more, he will have in total 120p.

Write down the equation that represents the above statement.

Problem 2:

John has got £110 more than Agapi.

Write down the equation that represents the above statement.

Problem 3:

Manos has got 17 car cards more than football cards.

Write down the equation that represents the above statement.

Problem 4:

There are six times as many students as teachers in this school.

Write the equation that represents the above statement.

Problem 5:

Kathy has half the money she had yesterday.

Write down the equation that represents the above statement.

Problem 6:

Peter's father is 183cm tall. Peter wanted to know how tall he is and he climbed on a chair which was 60cm high. When her sister asked him how tall he was, he answered: "Now that I am on this chair, I am 13cm taller than dad is".

Write down the equation that represents the above statement.

Problem 7:

Tom's father is 5 years older than three times the age of Tom.

Write down the equation that represents the above statement.

Problem 8:

In a cafeteria, for every four people who take strudels, five take cheese pie.

Write down the equation that represents the above statement.

Problem 9:

A breeder owns cows and calves. If he sells one cow and three calves, twice per year, he raises £25 more than if he sells three cows and one calf, once a year.

Write down the equation that represents the above statement.

Problem 10:

Diophantu's age.

He was a child for one third of his life. After a twelfth more his cheeks were bearded. After a sixth more he got married and five years later he fathered a son. The boy died when he had reached half of his father's age. Four years later Diophantus died too.

Write down the equation that represents the above statements.

the full lay out as it was given to the students is presented in Appendix D

The way the question is posed is also a factor that influences success. In this research, *relation* statements have been used in the word problems, even if they are more difficult for the students to recall and manipulate according to research mentioned in chapter three. This research tried to give compare problems with a form as straight and plain as possible, in order to examine the students performance under these conditions. In order to do that the following guidelines were followed:

- *no difficult vocabulary was used*
- *the grammar and the syntax were as plain as possible*
- *relational propositions were used (see page 30)*
- *the sentences were not given in inconsistent language (in Mayer's (1987) classification, see page 31-32)*
- *the subject of the variable was concrete for example 'Tom has five marbles' and not abstract as 'Someone has five marbles', in order to be easier for the student to label the unknown variable*
- *no extraneous information was given*
- *the Z-demand of the problems was increasing (the way problems were put into a scale of Z-demand is discussed below)*

The instructions given to the students were:

- *Read the problem carefully.*
- *Name the variables you are using; you are free to chose the symbol you want.*
- *Write down the equation that you think represents the above statement.*
- *You do not have to solve the equation; because an answer is not been asked from you.*
- *If you are stuck, carry on with the next problem.*
- *Check the examples given whenever you do not understand what you have to do.*
- *You have 30 minutes for the whole test.*

Two examples were given to the students who were asked to read carefully and ask questions if something was not clear (see Appendix D).

5.6.1 Performance in the Mathematics Test

The problems were each marked on a right-wrong scale. The correct answer was marked with 1. Thus, the top score is 10 and this can be thought as excellent. The test was given to lykeio students and they were supposed to have been taught these problems in gymnasio, yet only 5.6% of them were excellent. The mean performance was 6.6 and this indicates the difficulty associated with such problems. In the following paragraphs there is an attempt to correlate the achievement in the mathematics test with the working memory capacity of the students and their learning styles.

5.6.2 Performance in the Mathematics Test versus Working Memory Space Capacity

It has been assumed that there might be a relationship between working memory space capacity and achievement in representation of algebra story problems. Therefore, a comparison between students' working memory space capacity and their mean scores in the mathematics test in every X-space category was carried out (Table 5.3). According to this table, students with high working memory space (X=7), did better in the mathematics test than these with lower working memory space capacity (X=6 or X=5) (students' performance in each problem in every X-space capacity group is presented in Appendix A-2).

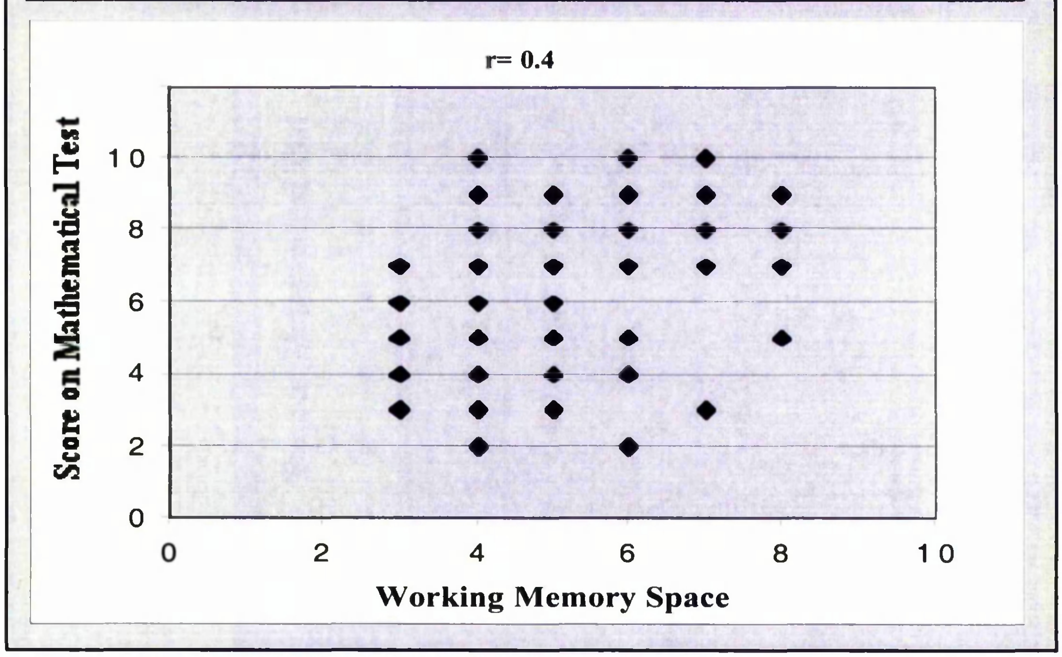
Table 5.3: Working memory space capacity of pupils related to mean scores in the mathematics test

GROUP (X-Space)	MEAN SCORE IN MATHEMATICS TEST
X = 5	6.0
X = 6	7.1
X = 7	7.8

A scatter diagram was plotted for the two variables: X-capacity versus mathematics test scores (Figure 5.4), in addition to calculating the Pearson correlation coefficient (r). There was a positive correlation between working memory space (X-capacity) and mathematics score (r= 0.4), significant at the 0.1% level.

The regression statistic method was used to determine to what level is the distribution of the score in the mathematics test explained by the working memory space capacity of the individuals. The total distribution of the dependent variable in the regression model (which is the scores of the students in the mathematics test) is 16% explained by the working memory space variable which is significant at 0.1% level (for a detailed analysis of the regression model see Appendix A-3).

Figure 5.5: Scatter diagram of working memory space versus performance in the mathematics test



5.6.3 Classification of the Problems According to their Z-Demand

The problems were classified by means of their *Z-demand.* According to Johnstone and El-Banna (1986), failure occurred in chemistry tests when the demand of the questions (tasks) exceeded the students' working memory space capacity (X-space). Working memory had reached what was described by Johnstone & Wham (1982) as a 'state of unstable overload'. These researchers defined the demand (Z) of a question as "the maximum number of thought steps required by the least able pupil to reach a solution". The Z-demand categories are five (3-demand to 8-demand). It was believed that this phenomenon of overloading of the working memory capacity might explain the difficulties of the students in algebra story problems representation.

In this research the problems given to the students are different from those used by Johnstone and El-Banna. It is extremely difficult to determine the necessary thought steps that lead to solution in the algebra story problems because they are not of algorithmic nature as chemistry problems. A lot of different mental procedures are taking place in representing the word problems like: text comprehension, translation from real language to mathematics notation, use of symbols, problem schemata, relationship between words and relationship between variables, holding and manipulating information as well as values, and many more. Every individual is more likely to have his/her own way of solving the problem. These are the reasons why this classification cannot be absolutely certain.

In order to put the problems into a scale of difficulty according to their Z-demand in this way, the opinion of experts in this field was asked. As a second step these assumptions were tested in a pilot project, with the use of a small sample of 20 students from the University of Glasgow (some of whom were Greek students, graduates of Greek high schools). These students were asked to write down the equation that represents best the given statement and the results taken from this pilot research were used in order to give to the test its final form.

The problems were classified in five Z-demand categories. The Z-demand occurred in the amount and the type of information that was given to the students and the whole mental procedures that are needed for the representation. This gradual difficulty according to Z-demand was developed by the following ways:

- *more information was given; the equation to be produced was more complex*
- *different calculation had to be used (according to research and experience, some calculations are more difficult to understand and to use than others, for example multiplication is more difficult than addition and division than subtraction; also students find fractions and analogies very difficult to manipulate etc.).*

Thus, the Z-demand of a problem is indicating 'the complexity of the equation acquired' which is slightly different from the 'maximum of thought steps' used in Johnstone's & El-Banna's study because of the different nature of the task. According to the approach adopted here, the following problem was defined as a 5-demand problem (middle complexity):

Problem 7

Tom's father is 5 years more than three times the age of Tom.
Write down the equation showing the above statement.

Solution:

X: I call the age of Tom's father
Y: I call the age of Tom
the equation is: $X=3Y+5$

An example of problem with 7-demand is the following:

Problem 9

A breeder owns cows and calves. If he sells one cow and three calves, twice per year, he raises £25 more than if he sells three cows and one calf, once a year. Write down the equation showing the given statement.

Solution:

C: I call the price of a cow
M: I call the price of a calf
the equation is: $(C+3M)*2= 25+3C+M$

The 'performance' (scale 0-1), which represents the number of pupils who did a representation of a problem of a particular Z-demand correctly divided by the total number of pupils attempting that problem, was calculated for all the individual groups. The Z-demand of every problem and also the students performance in each category is presented in the following table (Table 5.4). The first problems are deliberately easy, so is problem 7, even though it is placed right after problem 6 in order to increase students' self confidence in the beginning and the middle of the test.

Table 5.4: The performance of the students with X-working memory capacity to the problems of different Z-demand

	Z=3	Z=4	Z=5	Z=6	Z=7	Z=8
X=5	0.90	0.80	0.72	0.37	0.18	0.08
X=6	0.93	0.80	0.85	0.67	0.35	0.25
X=7	0.96	0.92	0.89	0.68	0.58	0.26
Problem	*1,2,3*	*4,5*	*7*	*6,8*	*9*	*10*

According to Johnstone & Wham (1982) hypothesis, a pupil with a working memory capacity of X=5 should be able to solve problems that had a Z-demand of 5 or less. Similarly, pupils with working memory capacity of X=6, should be able to solve tasks with Z-demand 6 or less but when Z-demand exceeds the X-space then performance should drop down dramatically. This hypothesis is tested in this project. The following figures (Figure 5.6, Figure 5.7 and Figure 5.8) show the performance of the students with working memory capacity X in the mathematics test.

Figure 5.6: The performance of students with X=5 in the mathematics test

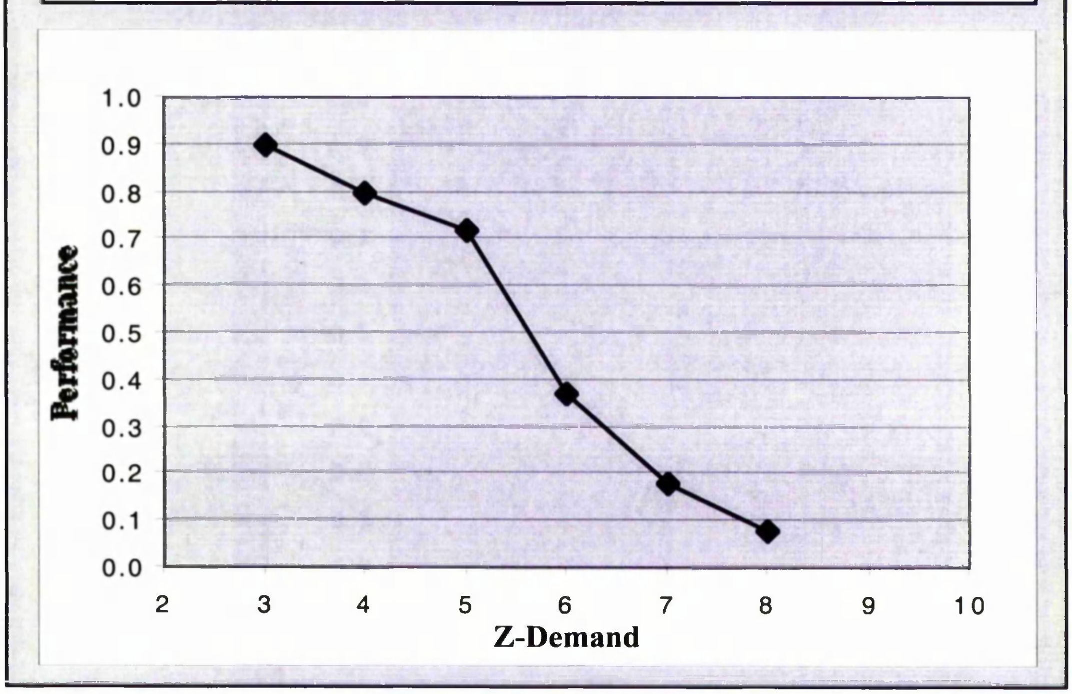


Figure 5.7: The performance of students with X=6 in the mathematics test

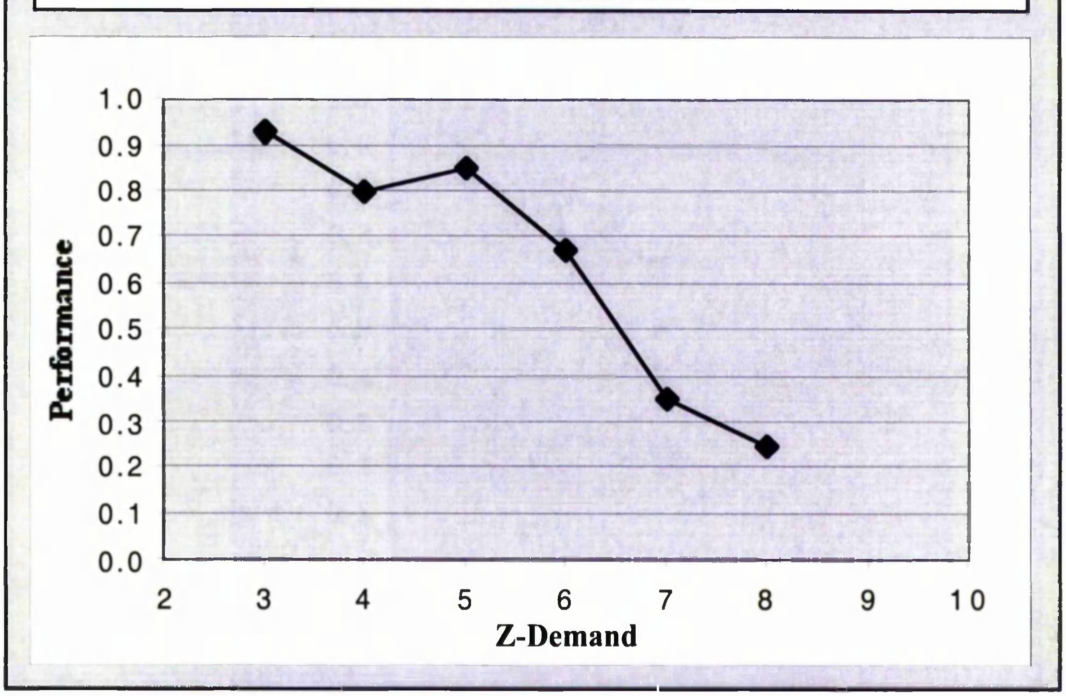
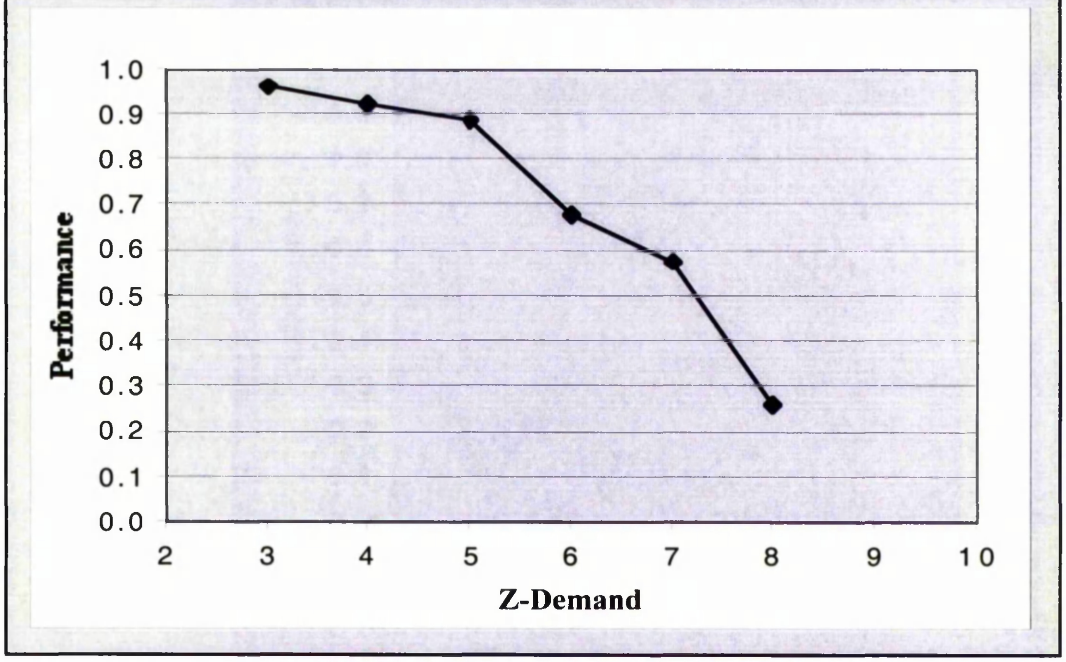


Figure 5.8: The performance of students with X=7 in the mathematics test



Even if the results coming out of these graphs do not conform exactly with the idealised curves (Figure 2.3) shown in chapter two (probably because of the difficulty to classify the questions), there are distinct similarities, with performance falling considerably as the demand of the questions increased beyond the X-space of the students group. Thus, when the demand of the question exceeds 5 in the X=5 students group (Figure 5.6) students performance declines markedly. The same happens when the Z-demand of the question exceeds 6 in the X=6 group (Figure 5.7) and 7 in the X=7 group (Figure 5.8). This indicates that as the amount of information which needs to be processed is increasing and exceeds the working memory capacity of the individuals, performance drops down considerably.

These results shows that overload of working memory space could be responsible for students' difficulties in algebra story problems representation. In addition to what the patterns of the graphs shows, from the marking of the test it was observed that students were forgetting important data from the equation. Most of the incorrect representations were due to the fact that not all variables were used even when the logic, the symbols and the structure was right.

5.6.4 Other Results from the Mathematics Test

Other results coming from the marking of the tests are now discussed. In problem 4 (*there are six times as many students as teachers in this school*), students failure was not as high as it appears to be in previous research mentioned in chapter three. Even though, the wrong representation of this problem was due to the 'reverse problem'. Students tended to write an equation such as *6 Students = Teachers (see page 31).*

The same problem was also identified in problem 8, where students were asked to write down the analogy of cheese pies and strudels. There is limited success in this question. Many students did not present an equation at all, although the others that wrote an equation which was wrong, most of time it was because the analogy was the reversed one.

In problem 9 most of the students did not take into account the 'twice per year' proposition which is a '*relevant fact*' proposition according to Mayer (1982b) (see page 30). The incorrect representations of the other problems were due to many different reasons. The most usual are: not all the data were used, the wrong calculations took place, the naming of the variables was not appropriate.

5.7 Performance in Mathematics Test versus H.F.T Scores

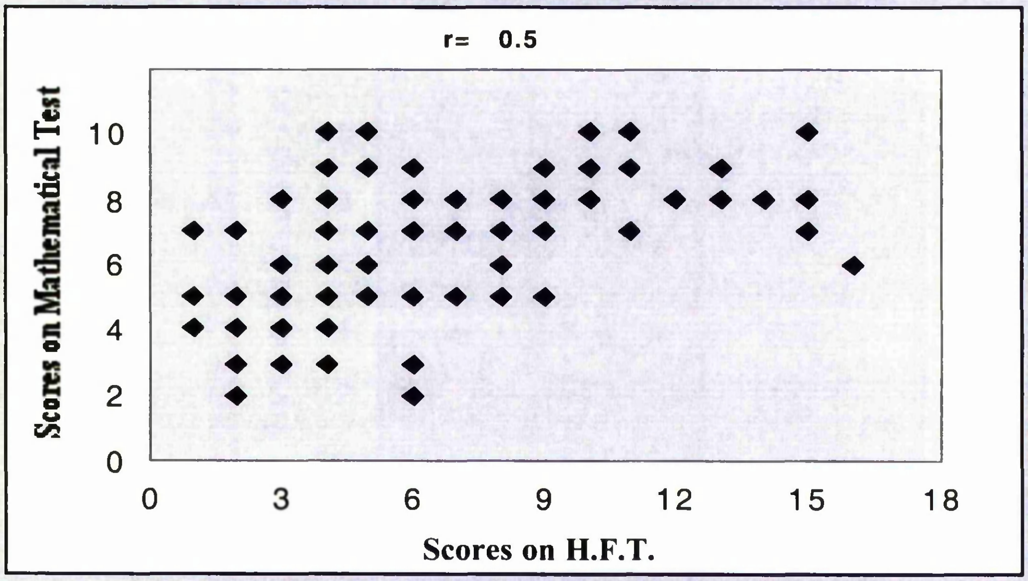
There is a significant correlation between the students' scores in H.F.T. and their scores in the mathematics test coming from the data of the sample. In table 5.4 it is shown that field-independent students had better performance than field-dependent students.

Table 5.5: Learning styles related to performance in the mathematics test

CLASSIFICATION OF THE SAMPLE ACCORDING TO THE H.F.T SCORES	*NUMBER OF PUPILS*	MEAN SCORE IN MATHEMATICS TEST
FIELD-DEPENDENT	*32*	5.5
FIELD-INTERMEDIATE	*33*	6.6
FIELD-INDEPENDENT	*25*	8.2

The Pearson correlation coefficient (r) between the students' scores in mathematics and the scores in the H.F.T. indicated a positive correlation (r=0.5), significant at the 0.1% level. The regression model was applied to examine the relationship between cognitive style and achievement in mathematics. According to that, the total distribution of the dependent variable (achievement) has been explained by 25% by the independent variable which is the students' degree of field-dependence/independence (significant at 0.1%) (see Appendix A-4). In the Figure 5.9, a scatter diagram for these two variables is presented.

Figure 5.9: Scatter diagram of scores in H.F.T. versus performance in the mathematics test



5.5.8 The Influence of Working Space and Learning Styles in Mathematics Achievement

The analysis of the data in the previous paragraphs indicated that there is a relationship between the two psychological factors measured in the research and the achievement in the mathematics test. In this paragraph, these two factors are brought together in relation to the mathematics achievement. In the following table (Table 5.4) , the sample of the students has been subdivided according to their X-capacity and field-dependence. For each group there is a value of the mean score in the mathematics test (the same table with the number of pupils in each category is presented in Appendix A-2).

Table 5.6: The F.D/F.IND learning style and X-space classification versus the mean scores in the mathematics test

GROUP	F.D	F.INTERM	F.IND
X = 5	5.0	6.1	7.8
X = 6	5.9	7.3	8.3
X = 7	7.3	7.3	8.4

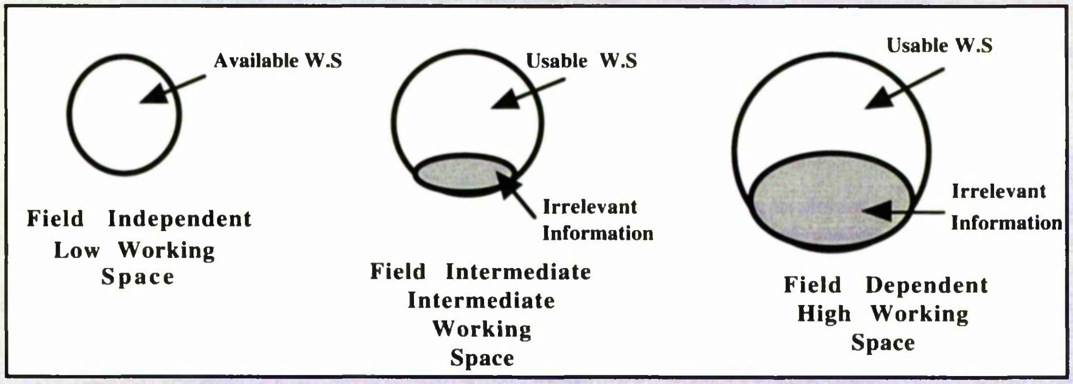
(sample of 90 students)

This table indicated the following

- *There is a steady improvement in the students' scores as they moved across the table from field-dependence to field-independence in all X-space groups.*
- *There is also a steady improvement in the students' scores as they moved across the table from X=5 to X=7 in all field-dependence groups.*
- *When the scores in both psychological tests were increasing, the X-capacity from X=5 to X=7 and the field-dependency from F.D to F.IND, achievement is also increasing, reaching the best value for the group of field-independent students with working memory capacity X=7.*
- *Field-dependent students with working memory capacity X=7 had the same mean score with field-intermediate students with working memory capacity X=6 and almost the same with field-independent students with working memory capacity X=5 (see the diagonals in the Table 5.5).*

The first three statements indicated again that these two psychological factors influence achievement in mathematics test. As far as the last statement (which indicated that there is no great difference in performance between low working memory capacity-field independent students and high working memory capacity-field dependent students) is concerned, Johnstone *et al* (1993), based on results which came out of research in chemistry education, suggested a possible explanation. According to this explanation, field independent and low working memory space students have the ability to distinguish the important information from the irrelevant one and they can use the whole working memory space more efficiently. On the other hand, field dependent and high working space students do not have this ability and part of their working space is occupied by irrelevant information. Thus, the former and the latter have almost the same working memory space capability and therefore similar performance in an educational task. The above is visually represented in Figure 5.10.

Figure 5.10: Usable working memory space capacity



As a final step in the analysis of the influence of the two psychological factors on achievement, the multiple regression model was applied. This time the dependent variable is again the scores of the students in the mathematics test and there are two independent variables, the X-capacity scores and the scores to the H.F.T. Both these variables explain the total distribution of the mathematics scores by 31% (at significance level of 0.1%) (see appendix A-5). This model was used just as an indicator of the influence of both psychological subjects to mathematics achievement. The results of this analysis suggests that there must be other variables that influence achievement. An effort to identify as many of them as possible took place in the second stage of this research presented briefly in the next chapter.

Chapter Six

Other Factors Related to Algebra Story Problems Representation

The second stage of this research arose from the results of the first stage. In the first stage, the way two psychological factors affect achievement in mathematics were examined: the working memory space capacity and the field dependence/independence of the students. Even without applying the regression model, it would be reasonable to assume that these two are not the only factors affecting performance on scientific tasks. Thus, in this second stage, an attempt is made to discover what other psychosociological factors could be responsible for a good or a bad learning process.

6.1 Aim of the Second Stage

In order to identify other possible factors that affect students' performance in algebra story problems representation, a questionnaire was designed. The aim of this questionnaire was to find out about the students' attitudes towards mathematics and some personal information for each student. This might throw light on possible reasons for students' success in algebra story problems.

Factors touched upon in the questionnaire included: like or dislike of mathematics; motivation related to further studying, family and school influences. It is recognised that, with a sample of 90, clear cut answers are unlikely but it was hoped that the approach might given some general indications as well as defining more clearly areas for future research.

6.2 The Design of the Questionnaire

The questionnaire given to the students contains questions either taken from the international literature of mathematics education (which was presented in chapter three) or developed for the aims of this project. The questions were covering the following areas:

- *personal information*
- *attitudes towards mathematics*
- *some aspects of school performance*
- *influence of the students' close environment*

Each of these categories will be explained in more details below:

Personal information contains the following:

- age
- class
- destination of studies chosen

the students' attitudes toward mathematics was explored using the following ways:

- in order to investigate the *'extrinsic mathematics motivation'*, described as the desire to achieve mathematics *awards and recognition*, as a possible factor, a question was asked about whether the students of the sample have participated in a mathematics competition, like the one which takes place annually in high schools all over country, organised be the Hellenic Mathematics Association.

- The students were asked whether they *like or dislike* mathematics and why, and also whether they enjoy trying to solve a problem in mathematics.

- They were asked whether they think of mathematics as an *important* thing to know and whether they believe that *everybody should know mathematics*.

- The *self confidence* of the students about their knowledge of mathematics was also explored.

- The pupils were asked to express their beliefs about what they think someone should do in order to be good in mathematics. They were asked to respond to the question whether they think that being good in mathematics is a matter of *luck*, *general intelligence*, or *hard work.*

- They were also asked to respond to the question of how they would like to see themselves in the near future. In this way, the students' *motivation* for further studying in the university or attending a job was explored.

- The students' preferences from the different branches of the Greek curriculum were asked. They were asked to show their preferences in comparison between two subjects, for example "what would they prefer between mathematics and classical Greek language classes".

- *Students were asked to write down their marks of the last term in a number of subjects in order to see which were strong and weak subjects.*

- *Their parents' level of education was asked in order to see if this might influence their attitudes towards mathematics or their achievement in mathematics.*

6.3 Instructions Given to the Students

The questionnaire was very simple to understand and complete. Most of the questions could be answered with just one tick (or as many ticks as they wished in a few questions), in the box which represented best the student's opinion. There were also a few questions where the students could write down their answer in their own words. They were asked to put a name, any name or any label, that they have used in the previous tests in order to put all the tests together for the analysis (the full version of the questionnaire is presented in Appendix E).

Even though it was not possible to test the validity of the questionnaire in a pilot stage as with the mathematics test, a short discussion with some students from the sample provided very important information for the analysis.

6.4 Method of Analysis

The data of this research were handled by the use of statistical methods, mainly correlation. The responses to the questions were marked and correlated with their scores in the mathematics test. Most of the questions were answered in a five points scale, of agree - disagree with the given statement. An example is given below.

	strongly agree	agree	neutral	disagree	strongly disagree
Everybody should learn mathematics	☐	☐	☐	☐	☐

There are three different ways of correlation in statistics. The correlation that has been previously used in this project is the Pearson rank order correlation coefficient (label with the letter r). The Pearson's correlation coefficient is the most common one and it is used almost in any case, especially when the data came from measurement and they are records of a scale. When the data are 'categorial', which are records of qualitative or quantitative category, the Kendall's tau-b correlation formula is more appropriate (label by the Greek letter τ). Depending on the questions needed to be correlated and the data available, one or a comparison of the two correlations is used in the following analysis. When both factors that need to be correlated uses categorial data then only the Kendall's tau-b correlation is used.

In this research, the attitudes towards mathematics is not measured by a number coming from the sum of scores according to the answers to different questions. Consequently, in order to examine how attitudes influences performance, each question's response is manipulated individually (Reid, 1978) (*correlation tables are presented in Appendices A-5, A-6*).

6.4.1 Factors Related to Achievement in the Mathematics Test

The results that follow were not surprising and they are presented in brief summary. Motivation for further studying is highly correlated with the students performance in the mathematics test ($r=0.45$, $\tau=0.38$, $p<0.01$). The self confidence was also positively correlated with the performance ($r=0.51$, $\tau=0.43$, $p<0.01$). As was expected, students who responded positively to the question whether they enjoy solving mathematics problems did better in the mathematics test ($r=0.43$, $\tau=0.33$, $p<0.01$). Students that like mathematics had better performance in the mathematics test than those who do not

($r=0.58$, $\tau=0.51$, $p<0.01$), and students that believe for themselves to be good in mathematics achieved higher scores in the mathematics test ($r=0.42$, $\tau=0.34$, $p<0.01$). (It is recognised that many of the probabilities obtained may be considerably less than 0.01. This is discussed in Appendix A-7).

According to the above, attitudes towards mathematics are positively correlated with achievement in mathematics test. It is therefore logical to assume that students who believe they are good in mathematics like mathematics and want to study mathematics further, are the students that do well in mathematics. The correlation applied to two variables is incapable of showing which of these two variables is the cause and which the effect in the relationship between them. The correlation formula only provide the level of the relationship between these two variables.

In this case, it is possible to assume that a positive attitudes towards mathematics helps achievement in mathematics. Equally, experience shows that achievement in mathematics helps to develop positive attitudes toward mathematics. Each of these two 'feeds' off the other. The correlation values give a further indicator of our experience and a reason to trust the conclusions coming out of the questionnaire.

Highly correlated were the responses to the question whether the students like mathematics and whether they think they are good in mathematics ($\tau=0.52$, $p<0.01$) and between the question whether they like mathematics and whether they understand a new mathematical concept easily ($\tau=0.41$, $p<0.01$). Since we know that there is a continuous interactivity between attitudes towards mathematics and achievement, the teacher should try to make attitudes as positive as possible. Students self confidence can be reinforced by many ways. The use of an easy example in the beginning of the presentation of a new concept, or an easy exercise in the beginning of a test, helps student's confidence, which in turn helps his/her further achievement. The same would happen with the other factors that are affected by each other (like motivation).

The educational level of the father is highly correlated with students' performance in the mathematics test ($r= 0.42$, $\tau=0.35$, $p<0.01$) on the other hand the educational level of the mother was poorly correlated with lower significant level with students' performance ($r=0.21$, $\tau=0.18$, $p<0.05$). No significant correlation was found with the age of the students. A possible explanation to that could be the fact that the problems used in the mathematics test had been taught in gymnasio level and the sample of the students were from lykeio. No significant difference in achievement was found between the two sexes, although boys were slightly better than girls. The responses to the question whether they think of mathematics as something that needs luck, hard work, or intelligence to be good at, were not significant correlated to the performance.

6.4.2 Factors Related to Students' Motivation

The motivation for students to carry on with further education is correlated with the self confidence of the students. The correlation between these two variables is positive ($\tau=0.29$, $p<0.01$). High correlation was found between students' motivation and their father's educational level ($\tau=0.40$, $p<0.01$) even though it was poorly correlated with lower significant level with the mother's educational level ($\tau=0.21$, $p<0.05$). This is may be because of the father-centred way the Greek family is organised and the fact that only in the last 20 years are women also likely to go to university.

6.4.3 Other Results from the Analysis

Only three students of the sample had participated in a mathematics competition and two of them did excellently in the mathematics test. As far as the students' response to the question why they like mathematics, 38% answered that this is because of a good teacher they used to have and 21% because they understand the logic. Students were asked to write down their marks in different disciplines of the educational curriculum. From discussion with a number of students of the sample it was concluded that this question was not clear and it was not taken under consideration in the analysis. Some students completed this question with the marks of the last term and others with marks from the last term's examination.

6.5 Students' Preferences Between Different Disciplines

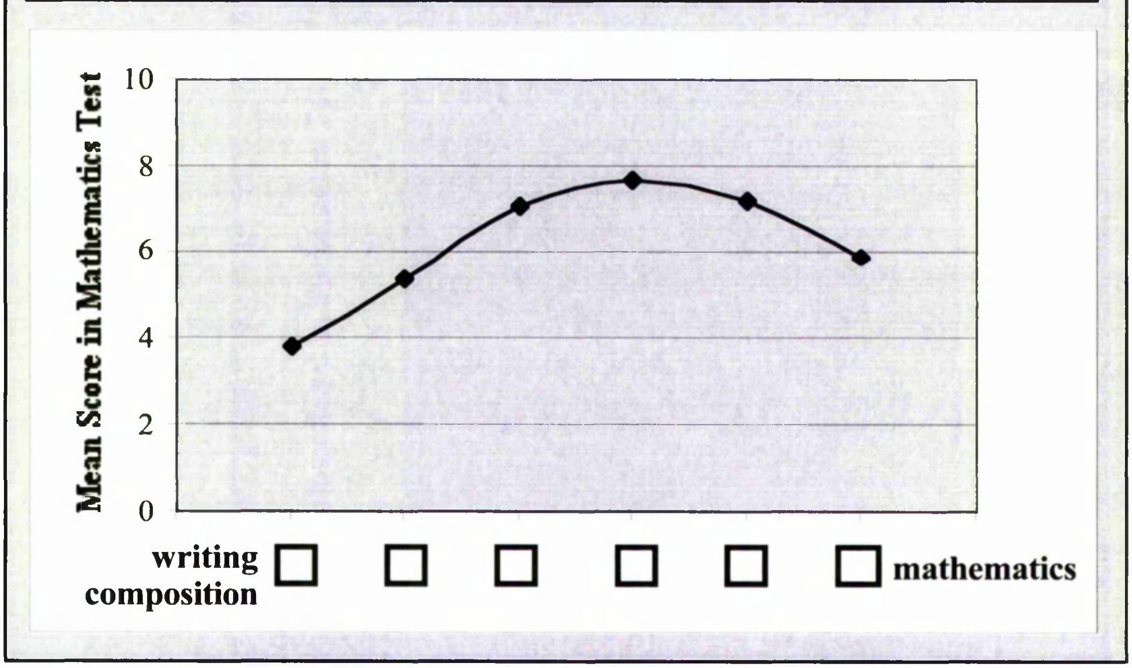
At this stage, the students of the sample were asked to indicate their preferences in some disciplines of the educational curriculum. Two different disciplines were given each time and a six point scale between them.The students were asked to tick one of the six boxes, the closer to the label, the stronger the preference. An example is given below.

mathematics □ □ □ □ □ □ chemistry

These questions were designed for this research. The responses of the pupils were related to their mean scores in the mathematics test. The results from this questions are presented graphically. The question itself was placed in the x-axes of the graph. This way it is easier to observe how the students' preferences for a subject affects success in the given mathematics test (Figures 6.1-6.5). Each of these graphs will be discussed in terms.

In Figure 6.1 the students were asked to show their preference between mathematics and writing composition. Writing composition is an important issue in the Greek education system. Students sit national examinations in writing composition. They are supposed to write their opinion on a given subject. Most of the times, this subject refers to a matter of general interest, for example "The role of the mass media in influencing and changing the way society thinks". The students have to be able to organise their thoughts in a coherent way, making use of arguments, and general information in order to convince other towards their point of view. The use of language, syntax, grammar and vocabulary is very important for achieving a good mark.

Figure 6.1: Students reference between mathematics and writing composition versus mean scores in the mathematics test

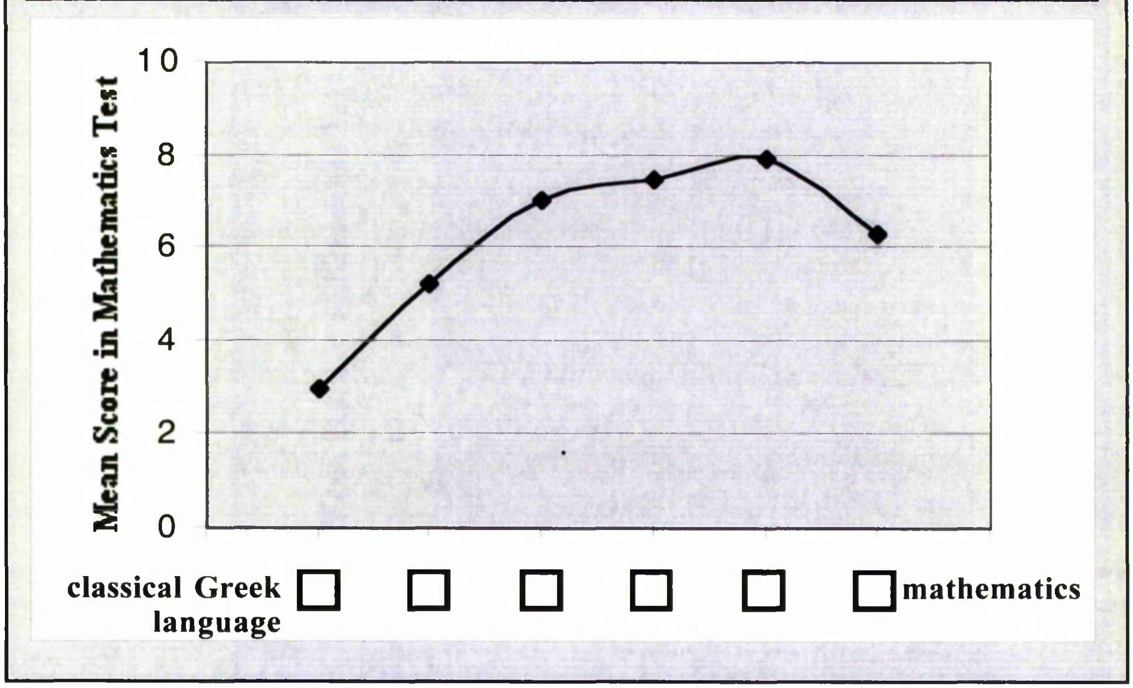


As it is shown in the graph in figure 6.1, students with middle preference between these two subjects of the discipline have the better performance in the mathematics test. Students choosing mathematics as a concentration subject tend not to be so good in language. This is the reason why the pattern of the graph is not, therefore, exactly what was expected. It was expected that students who prefer mathematics should be the one with the best performance. As mentioned before, preference most of the times is very close to what someone is good at. A possible reason for this pattern would be that the problems given to the students to solve in the mathematics test are not just mathematics exercises but they also involve good knowledge of language. In this specific area of mathematics, the algebra story problems, language is a very important factor for success. Students with a good level in language classes, are better in text comprehension and vocabulary interpretation, and this affects their total performance.

Furthermore, writing composition is a logical task for students in Greece. A lot of thought has to be put together to produce a meaningful representation, just like in the representation of algebra story problems. Previous knowledge, methods, language, symbols and plan have to be processed in order to produce the final result. As the graph indicates, a balance in preference would yield the best performance in algebra story problems.

In Figure 6.2, the graph indicates almost the same thing as the previous one. In this question, the students were asked to show their preference between mathematics and classical Greek language classes. Again students with middle preference between these two subjects have better performance in the mathematics test.

Figure 6.2: Students preference between classical Greek language and mathematics versus performance in the mathematics test



Classical Greek language is also an important issue in the Greek education curriculum. Students take national examinations in ancient Greek language. Mathematics and classical Greek are the two subjects that hold the two edges in students' preference. Students that take the 'science' direction of studies, most of the time is because of their dislike towards classical Greek and vise versa.

On account of the similarities with the modern Greek language, the students' native language, classical Greek language is taught in comparison to the modern one. The students have to learn the grammar, the syntax and the vocabulary of this language in order to take good marks. Additionally, a holistic analysis of the meaning, the purpose and the structure of a known or unknown classic text (taken from an historic or a philosophical document from the classical period) is part of the assessment of the classical Greek language. This makes it very similar as far as the mental processes involved with the algebra story problems representation. Students are asked to translate from one language to the other, recognise the style of the writer and make a successful analysis of the meaning of the text.

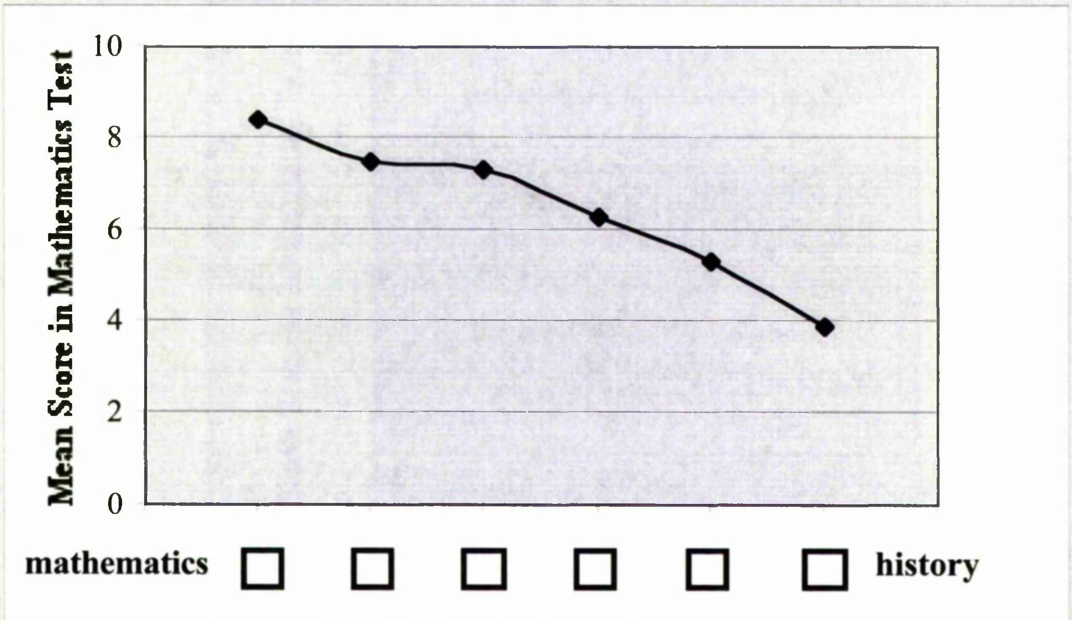
Even though it was expected that students with positive preference in mathematics would have the best performance and that this performance would fall down as the preference would move towards the classical Greek's edge, according to the graph students with middle preference have the best performance. Based on the way classical Greek language is taught in Greek high school mentioned before, this result makes sense. Students with good knowledge of language and the way language functions, have better chances in succeeding in representing problems given in real language as the algebra story problems that have been given to the sample. The explanation would be almost the same with the one referring to the Figure 6.1.

Classical Greek language classes as well as writing composition demands several mental processes at the same time. It is not possible to have a good performance in these subjects with rote learning. Remembering things by heart would not be helpful at all. This makes it somehow similar to mathematics. All three are logical tasks. These conclusions agrees with the conclusions of the research carried out by Mpolis & Tzani (1993) in Greek high schools. Students performance in mathematics and language test were examined and the conclusions were that students that are good at language did better in the use of mathematical symbols than those that were weak in using language. These results supports the arguments for the benefits of the general (holistic) education. Students that are doing well in these different disciplines of the curriculum are also better in representing algebra story problems.

The case is different, however, when it comes to history classes. When students were asked to show their preference between history and mathematics, the graph in the Figure 6.3 was produced.

This graph shows that as the preference for mathematics increases, the performance in the mathematics test increases too. Students that like mathematics, do not like history, even though the latter is at the centre of the education curriculum from the primary to the last year of high school. History is on the same direction of studies (the last two years of high school) with the classical Greek language although it is taught in a totally different way.

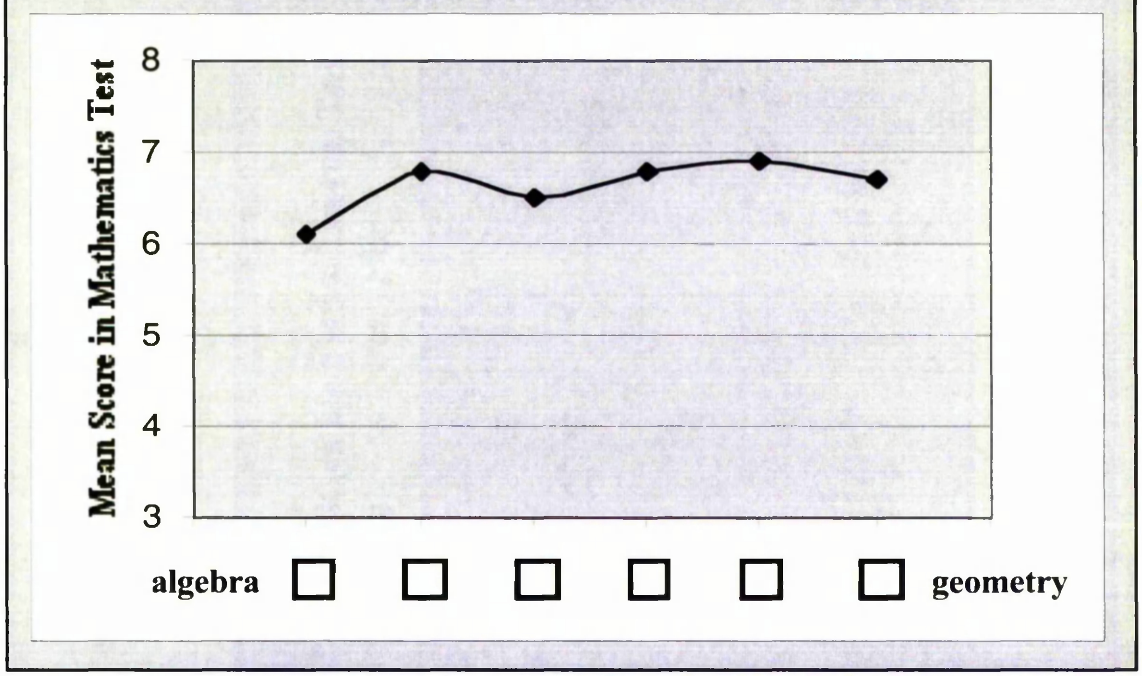
Figure 6.3: Students preference between mathematics and history versus performance in the mathematics test



As mentioned in chapter four, assessments most of the times determine the way the lesson is taught. A good example of this is the history classes. In the national or the leaving examinations, the best mark goes to the student that has recalled the specific part of the textbook that it is asked, as accurately as possible. Learning by heart is necessary for a successful performance in history classes. No logical processes are taking place. This could be an explanation for the differences in the pattern of this graph compared with the previous two that came out from the students' sample.

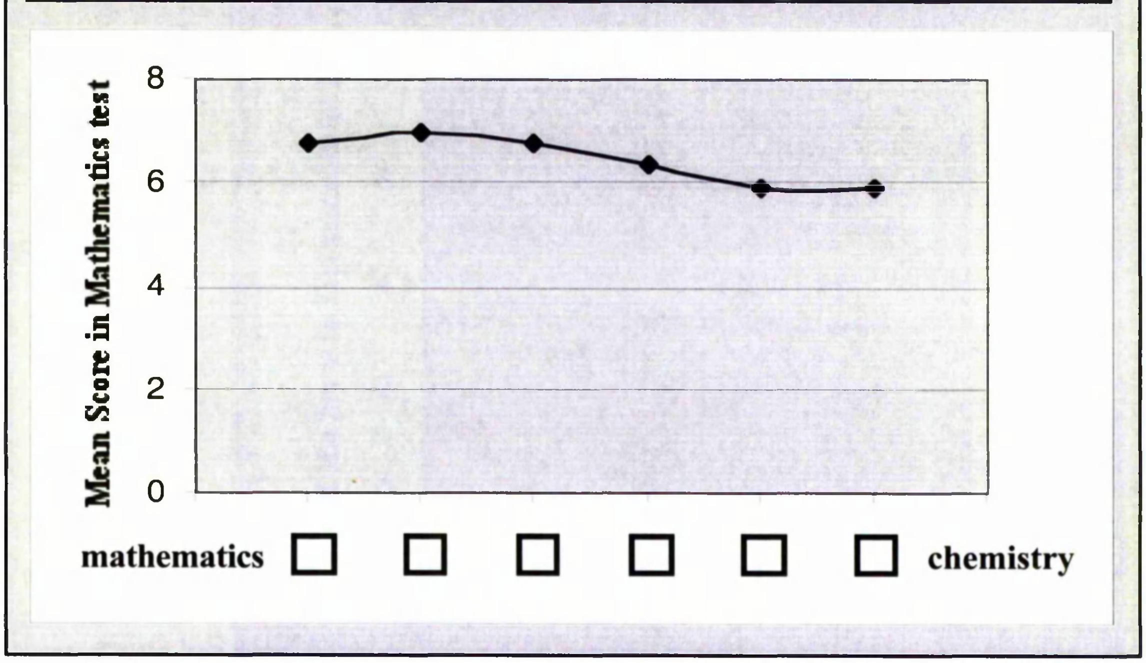
Students were also asked to tick their preference between algebra and geometry and also between mathematics and chemistry. Figure 6.4 and Figure 6.5 shows the performance of the students of the sample according to their preferences.

Figure 6.4: Students preference between algebra and geometry versus performance in the mathematics test



From the graphs in both Figure 6.4 and Figure 6.5, no specific pattern that could indicate differences between students' preference for the one or the other subject emerge. Between algebra and geometry the performance is almost the same. Even if the problems given to the students were not geometric ones, no differences have occurred. The same can be seen from the Figure 6.5. Chemistry in the Greek education system is in the same direction of studies with mathematics. Most of the times, students doing well in chemistry, also do well in mathematics. Chemistry and mathematics are both logical tasks, even though in chemistry many things need memorising.

Figure 6.5: Students preference between mathematics and chemistry versus performance in the mathematics test



Chapter Seven

Review, Conclusions, Discussion and Recommendations for Further Work in Representation of Algebra Story Problems

The primary purpose of this research study was to investigate students' capability in applying mathematics in real life problematic situations. In order to do that it was chosen to investigate students' performance in representing algebra story problems. Two psychological factors thought to have an important influence on pupils' performance in representing algebra story problems were measured: working memory space capacity and field-dependence/independence. Students' attitudes towards mathematics and their influence in mathematics achievement were also explored.

Previous work suggested the following:

- There may be a direct relationship between working memory space capacity and students' performance in algebra story problems representation.

- Failure may occur in algebra story problems representation task when the Z-demand (difficulty of a problem placed on the pupil's working memory space capacity) went beyond the pupil's working memory space capacity.

- Field-dependence/independence, cognitive factors, may influence performance in problem representation.

- Students attitudes toward mathematics may be related to achievement in algebra story problems.

7.1 A Review of this Research Study

At the first stage of this study, the working memory space capacity and the degree of field-dependence/independence (F.D./F.IND) were determined for a sample of 90 students aged between 15-17 years from a Greek private support high school. The 90 students were a typical sample of the population. To determine the working memory space capacity of the students the Digit Backwards Test (D.B.T.) (Appendix C) was used and to measure the degree of field-dependence/independence of the pupils the Hidden Figure Test (Appendix F) was used.

In order to test students capability in representing algebra story problems and the role that working memory space (X-space) and field-dependence/independence (F.D/F.IND) have in success in this task, a mathematics test was designed (Appendix D). The test included 10 algebra story problems taken from the literature or produced for this project. The students were asked to write down the equation that represents the given statement. All the problems were 'compare' problems. Information processing model and other approaches to the difficulties students have with these problems were applied to design this mathematics test and also to put the problems on a scale of difficulty (Z-demand) they placed on the pupils working memory space capacity .

At the second stage of this study, an attempt was made to identify other possible factors that influence achievement in mathematics and especially in algebra story problems representation. In order to do that, a questionnaire was designed (see Appendix E). The aim of the questionnaire was to investigate students' attitudes toward mathematics, their preferences, likes/dislikes, motivation and also collect some information about them and their close environment. The questionnaire was applied to the same sample of students in order to be linked with the other results.

Throughout this research, many interesting points have been raised concerning the influence of many different factors in students' achievement in mathematics. Factors like the role of the teacher and the role of the student in the learning process as well as the interaction between them. In the teaching and learning process, it could be assumed that there is a broadcasting device (the teacher) and a receiving device (the student), the message (what is transmitted) and the medium (school and teaching process). In order to be able to make decisions about which is the best way to teach something all these four variables should be examined and the way the one affects the other needs exploration.

Every single one of these variables is affected by many other variables and that makes it difficult to create a whole image of the teaching and learning process. That is also what makes research in education that interesting.

7.2 Findings and General Conclusions

A number of points are raised from the application of the psychological tests and pupils' performance in the mathematics test. An analysis of the results from the first stage presented in chapter five suggests that:

- A relationship exists between working memory space capacity and pupil's performance in the mathematics test. Thus, high working memory space capacity students performed better in the mathematics test than intermediate working memory space capacity students, and intermediate working memory space capacity students performed better than low working memory space capacity counterparts.

- Failure occurred in the mathematics test when the Z-demand was quite close to the pupil's designated working memory capacity (Figure 5.6, Figure 5.7 & Figure 5.8).

- There was a significant positive correlation between field dependence and achievement in the mathematics test. Students' performance in the test improved as the pupils went from being field-dependent to field-independent.

- High working memory space capacity and field-independent pupils scored better in the mathematics test than those who were field-dependent and of low working memory space capacity. However, there was no significant difference between low working memory space capacity/field-independent pupils, intermediate working memory space capacity/field-intemediate students and high working memory space capacity/field-dependent pupils.

An analysis of the results for the second stage presented in chapter six suggests that:

- Students' self confidence in mathematics was highly correlated with their performance in the mathematics test.

- The students of the sample who replied positively in the questions whether they like mathematics, whether they enjoy solving mathematical problems and whether they believe they are good in mathematics performed better in the mathematics test than the other students.

- Students' motivation for further studying in university was highly correlated to achievement in the mathematics test.

- The pupils who like mathematics are the ones who replied positively to the question whether they understand easily a new mathematical concept.

- Students' motivation for further studying was positively correlated to their self confidence and also to their father's educational level.

- The pupils who had middle preference between the subjects: mathematics - writing composition and mathematics - classical Greek language, performed better in the mathematics test.

- Students who preferred mathematics more than history classes had better performance in the given mathematics test than students who preferred history.

7.3 Suggestion for Teaching and Assessments

There are some key points that the results of this study suggest for teaching and also for assessments in algebra story problems.

- It is important for the teachers to know that working memory space capacity is limited and, whenever an overload occurs, students' performance declines markedly. In their teaching and also in their testing materials, they should be careful with the way they give the information to the students. The language used, the propositions, the vocabulary, the syntax and the amount of information given in a unit time are important factors for students' success. It is important to know that mistakes may be not due to the fault of the students but may be because the question was not asked properly.

- Students should be taught how to classify problems correctly in order to create the right and easy retrievable problem schemata. A way of doing this could be by giving to the students as many problems as possible from different categories to practise by themselves. This could help students create their own strategies for dealing with mathematical problems. Practise also helps students' confidence in problem solving. This could also be a way of reducing working memory space overload.

- A suggestion could be to teach students how to create visual representation when it is possible (graphs, tables, pictures). This may offer the students opportunities for them to develop strategies to avoid working memory space overload.

- Teachers should encourage students to identify necessary and sufficient information.

- Teachers, as well as authors of school textbooks, should also focus on students attitudes' towards mathematics. Easy examples before introducing a difficult concept helps raising the self confidence of the student and that tends to lead to better results. Also, when teachers design testing materials, an easy exercise in the beginning of the test have better results.

- As far as the curriculum is concerned, students should have general education. If mathematics could be taught together with physical sciences then it would be easier for the students to determine their applications. Good knowledge of language influences success in mathematics word problems.

7.4 Recommendations for Further Study

As a result of this research study a substantial number of questions have arisen regarding difficulties in representing algebra story problems that could be a point of departure for further research in this area. Some suggestions for future investigations are listed below:

- It would be interesting to examine the way students classify the problems in their long term memory creating mathematics schemata by creating students' mind and concept maps. It would also be interesting to investigate the way convergent/divergent styles of thinking influences success in algebra story problem representation.

- Different ways of presenting algebra story problems to the students and the way this affects their performance would be a study that could provide us with new teaching suggestions. The same problem could be given to the students using different ways (different vocabulary, syntax or maybe with a picture) in order to determine the best way for presenting these problems to the students.

- Nowadays, computers and new technological equipment exist in every school. There could be an attempt to design a computer program simulator that could change a visual representation of a problem according to the change of the equation that represents the problem. This way it could be emphasised the operative nature of equations. This could open new dimension in the teaching and learning problem representation strategies.

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List of Appendices

Appendix A

Statistical Results and Tables of the Study

Number of pupils of every working memory space capacity category who solved correctly each problem of the mathematics test and the mean performance

	Pr1	Pr2	Pr3	Pr5	Pr7	Pr4	Pr6	Pr8	Pr9	Pr10	w.m.s.
number of pupils	*48*	*47*	*43*	*37*	*40*	*40*	*26*	*12*	*9*	*4*	**z=5**
mean	0.94	0.92	0.84	0.73	0.78	0.78	0.51	0.24	0.18	0.08	**51 pupils**
number of pupils	*20*	*17*	*19*	*19*	*17*	*13*	*12*	*15*	*7*	*5*	**z=6**
mean	1.00	0.85	0.95	0.95	0.85	0.65	0.60	0.75	0.35	0.25	**20 pupils**
number of pupils	*19*	*18*	*18*	*18*	*17*	*17*	*16*	*10*	*11*	*5*	**z=7**
mean	1.00	0.95	0.95	0.95	0.89	0.89	0.84	0.53	0.58	0.26	**19 pupils**

(Pr1-Pr10: problems 1-10 of the mathematics test, w.m.s.: working memory space capacity of the pupils, mean: percentage of students with successful performance)

Descriptive statistics for the students' scores in H.F.T

Mean	6.4	Minimum:	1
Standard Error	0.4	Maximum:	16
Median:	6	Sum:	580
Mode:	4	Court:	90
Standard Deviation	3.6	Conf.Level:(95%)	0.75

The formula used for the classification of the sample in field-dependence/independence categories:

F.D < mean-0.5* Standard Dev.
F.D < 6.4 - 0.5 * 3.6
F.D < 4.6
scores: 0,1,2,3,4

F.D < F.INT < F.IND
scores: 5,6,7,8

F.IND >mean+0.5* Standard Dev.
F.IND > 6.4 + 0.5 * 3.6
F.IND > 8.2
scores: 9,10,11,...,20

The F.D/F.IND learning style and X-space classification versus the students' mean scores in the math test with number of students in each category.

GROUP	F.D		F.INT		F.IND	
	number of students	mean score	*number of students*	mean score	*number of students*	mean score
X = 5	*21*	**5.0**	*20*	**6.1**	*10*	**7.8**
X = 6	*7*	**5.9**	*7*	**7.3**	*6*	**8.3**
X = 7	*4*	**7.3**	*6*	**7.3**	*9*	**8.4**

Dependent variable: *Students' performance in mathematics test*
Independent variable: *Students' working memory space capacity*

Regression Statistics	
Multiple R	0.40
R Square	**0.16**
Adj. R Square	0.15
Standard Error	1.82
Observations	90

	df	SS	MS	F	Significance F
Regression	1	55.01	55.01	16.58	**0.000101535**
Residual	88	291.89	3.32		
Total	89	346.9			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
mathematics performance	3.49521989	0.79416513	4.40112484	3.0132E-05	1.91698235	5.07345742
X-space	**0.59209688**	0.1453985	4.07223512	**0.00010154**	0.303147689	0.88104606

From the above analysis the total distribution of the dependent variable which is the students' performance in the mathematics test, is 16 % (*R-square*) explained by the independent variable which is the students' working memory space capacity. The independent variable is statistically significant (*P-value <0.001*).

The regression analysis also provides the relationship between the two variables: the dependent and the independent one. Thus, according to the above table, increase by one point of the students' X-space (*scale2-8)* would increase performance by 0.59 (*coefficient value*) (*scale1-10)*.

In the next table, the independent variable is students' field-dependence/independence cognitive style.

Dependent variable: *Students' performance in mathematics test*
Independent variable: *Students field-dependence/independence*

Regression Statistics	
Multiple R	0.50
R Square	**0.25**
Adj. R Square	0.24
Standard Error	1.72
Observations	90

	df	SS	MS	F	Significance F
Regression	1	85.2407586	85.2407586	28.6677692	**6.77481E-07**
Residual	88	261.659241	2.97340047		
Total	89	346.9			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95.0%
mathematics performnce	4.88201771	0.37420015	13.0465413	2.7974E-22	4.138372975	5.62566245
F.D/F.IND	**0.27175587**	0.05075537	5.3542291	**6.7748E-07**	0.170890164	0.3726q2158

According to this table, the independent variable, which is the students' degree of field-dependence/independence, explains the total distribution of the dependent variable, which again is the students' performance in the mathematics test, by 25% (*R-square*).

The F.D./F.IND variable is statistically significant in the analysis (*P-value<0.001)*. The coefficient value indicates that increase by one unit in the student's degree of F.D/F.IND (*scale1-20)*, would increase his/her performance by 0.27 (*scale 1-10*).

In the next table both these independent variables, the X-space and the F.D/F.IND are put in the regression model. This way it is been explored in what level is the total distribution of the student's performance in the mathematics test be cause of these two variables.

Dependent variable: *Students' performance in mathematics test*
Independent variables: *Students' field-dependence/independence*
Students' working memory space capacity

Regression Statistics	
Multiple R	0.55
R Square	0.31
Adj. R Square	0.29
Standard Error	1.67
Observations	90

	df	SS	MS	F	Significance F
	Regression 2	106.570502	53.2852512	19.289421	**1.16472E-07**
Residual	87	240.329498	2.76240802		
Total	89	346.9			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
mathematics performance	3.11852498	0.72996746	4.27214243	4.9296E-05	1.667634547	4.5694154
F. D/F.IND	**0.22401806**	0.05185023	4.32048344	**4.119E-05**	0.120960039	0.32707608
X-space	**0.39078046**	0.14063193	2.77874636	**0.00668502**	0.11125907	0.67030184

When together in the model, both the independent variables, the students X-space capacity and their degree of F.D/F.IND stays statistically significant (*P-value <0.01 in both cases).* Together these variables explain 31% of the total distribution of the students' performance.

When these two variables are together in the model, their coefficient values falls down considering when they were alone in the model. This happens because there is a relationship between these two variables. Thus, when each of these variables were alone in the model, a part of it's effect was due to the other variable because of their relationship.

Both these variables are important for explaining students' performance in the mathematics test, when they are alone or together. Because of the fact that only the 31% if the total distribution is explained by these two variables, this means that other factors that influence students' performance have to be found.

Tables of Correlation From the Second Stage of the Research

Correlation Coefficients Values

	you have to be clever to be good at mathematics	I do not like mathematics	it is a matter of hard work	it is a matter of luck	I do not think I am good at mathematics	I understand easily a new concept	i do not enjoy solving problems
performance in the mathematics test	0.0751	0.5842**	0.1476	0.1286	0.4157**	0.3431**	0.4229**

Pearson Correlation Coefficient

	sex	age	i feel confident about my knowledge of mathematics	motivation for further studying	mother's educational level	father's educational level
performance in the mathematics test	0.0110	0.1900	0.5049**	0.4429**	0.2096*	0.4185**

**: *Significant level <0.01,* *: *Significant level <0.05 (2-tailed)*
(the values are all positive as if all the questions were positive)

Kendall's tau-b Correlation Coefficients

	performance in the mathematics test	I do not like mathematics	I feel confident about my knowledge of mathematics	motivation for further studying	I do not think I am good at mathematics	I understand easily a new concept
performance in the mathematics test		0.5078**	0.4285**	0.3766**	0.3349**	0.3275**
you have to be clever to be good at mathematics	0.0475					
I do not like mathematics	0.5078**		0.3900**	0.1581	0.5173**	0.4065**
it is a matter of hard work	0.1134					
it is a matter of luck	0.1014					
I do not think I am good at mathematics	0.3349**	0.5173**	0.4733**	0.1021		0.3132**
I understand easily a new concept	0.2942**	0.4065**	0.2856**	0.2848**	0.3132**	
i do not enjoy solving problems	0.3275**		0.3213**	0.0900	0.1632	0.1393
motivation for further studying	0.3766**	0.1581	0.2888**		0.1021	0.2848**
mother's educational level	0.1775*			0.2071*		
father's educational level	0.3478**			0.3911**		

Kendall's tau-b Correlation Coefficients
***: Significant level <0.01, *: Significant level <0.05 (2-tailed)*
(the values are all positive as if all the questions were positive)

It is likely that many of the correlation obtained have a significance level of considerably lower than 0.01. However the SPSS program have merely quoted at two significant levels using significance levels expressed related to unity. This is been retained in the discussion in page 68.

Appendix B

Data from the Research

Data from the First Stage of the Research

Student's No	F.D	w.m.	Pr1	Pr2	Pr3	Pr5	Pr7	Pr4	Pr6	Pr8	Pr9	Pr10	SUM
1	1	3	1	1	1	1	1	0	0	0	0	0	5
2	1	5	1	1	1	0	1	0	0	0	0	0	4
3	2	3	1	1	1	0	0	1	0	0	0	0	4
4	2	3	1	1	1	1	1	1	1	0	0	0	7
5	2	4	1	1	1	1	1	0	0	0	0	0	5
6	2	4	1	1	0	0	1	1	0	0	0	0	4
7	2	4	0	0	1	1	1	0	0	0	0	0	3
8	3	3	1	1	0	0	0	1	0	0	0	0	3
9	3	3	1	1	1	0	0	1	0	0	0	0	4
10	3	4	1	1	1	0	1	1	1	0	0	0	6
11	3	4	1	1	1	0	1	1	0	0	0	0	5
12	3	5	1	1	1	1	1	1	0	0	0	0	6
13	3	5	1	1	1	1	1	1	0	0	0	0	6
14	4	3	1	1	1	0	1	1	1	0	0	0	6
15	4	4	1	1	1	1	1	1	1	1	1	1	10
16	4	4	1	1	1	1	1	0	1	0	0	0	6
17	4	4	1	1	1	0	0	1	1	0	0	0	5
18	4	4	1	1	1	0	0	0	0	0	0	0	3
19	4	5	1	1	1	1	1	1	0	0	0	0	6
20	4	5	1	1	0	1	0	0	0	0	0	0	3
21	4	5	0	0	0	0	1	1	0	1	1	0	4
22	5	4	1	1	1	1	0	1	0	0	0	0	5
23	5	4	1	1	0	1	1	0	1	1	1	0	7
24	5	5	1	1	1	1	1	1	1	0	0	0	7
25	5	5	1	1	1	1	0	1	0	0	1	0	6
26	5	5	1	1	1	1	1	1	1	0	0	0	7
27	5	5	1	1	1	1	1	1	1	0	0	0	7
28	5	5	1	1	1	1	1	1	1	0	0	0	7
29	5	5	1	1	1	1	1	1	1	1	1	0	9
30	6	3	1	1	1	1	1	1	1	0	0	0	7
31	6	4	1	0	0	1	1	1	0	1	0	0	5
32	6	4	0	1	0	0	1	0	0	0	0	0	2
33	6	4	1	1	1	1	1	1	1	0	1	0	8
34	6	4	1	1	1	1	0	1	0	0	0	0	5
35	6	5	1	1	1	1	1	1	1	0	0	0	7
36	7	4	1	1	1	1	1	1	1	0	0	0	7
37	7	5	1	1	1	1	0	1	0	0	0	0	5
38	7	5	1	1	1	1	0	1	0	0	0	0	5
39	8	4	1	1	1	1	1	0	1	0	0	0	6
40	8	5	1	1	0	0	1	1	0	1	0	0	5
41	8	5	1	1	1	0	1	1	1	0	0	0	6
42	9	4	1	1	1	1	1	1	1	1	0	1	9
43	9	4	1	1	1	1	1	1	1	1	0	0	8

44	9	4	1	1	1	1	1	1	1	0	0	0	7
45	9	5	1	1	1	1	1	1	1	0	1	0	8
46	10	5	1	1	1	1	1	1	1	1	0	0	8
47	11	4	1	1	1	1	1	1	0	1	1	1	9
48	11	5	1	1	1	1	1	1	1	0	0	0	7
49	12	5	1	1	1	1	1	1	1	1	0	0	8
50	13	5	1	1	1	1	1	1	1	0	1	0	8
51	16	5	1	0	1	1	1	0	0	1	0	1	6
52	1	6	1	1	1	1	0	1	1	0	1	0	7
53	2	6	1	0	1	0	0	0	0	0	0	0	2
54	3	6	1	0	0	1	1	0	0	1	0	0	4
55	3	6	1	0	1	1	1	0	0	0	0	0	4
56	4	6	1	1	1	1	1	1	0	1	1	0	8
57	4	6	1	1	1	1	1	1	1	1	0	0	8
58	4	6	1	1	1	1	1	1	1	1	0	0	8
59	5	6	1	1	1	1	1	1	0	1	0	0	7
60	5	6	1	1	1	1	1	0	1	1	0	0	7
61	5	6	1	1	1	1	1	1	1	1	1	0	9
62	6	6	1	1	1	1	1	1	1	1	0	0	8
63	7	6	1	1	1	1	1	0	0	0	0	0	5
64	8	6	1	1	1	1	0	1	1	1	0	0	7
65	8	6	1	1	1	1	1	0	0	1	1	1	8
66	9	6	1	1	1	1	1	0	0	0	0	0	5
67	9	6	1	1	1	1	1	1	1	1	0	0	8
68	10	6	1	1	1	1	1	1	1	1	1	1	10
69	11	6	1	1	1	1	1	1	1	1	1	1	10
70	13	6	1	1	1	1	1	1	1	1	1	0	9
71	15	6	1	1	1	1	1	1	1	1	0	0	8
72	2	8	1	0	1	1	1	1	0	0	0	0	5
73	3	7	1	1	1	1	1	1	1	1	0	0	8
74	4	7	1	1	1	1	1	1	1	1	1	0	9
75	4	8	1	1	1	1	1	1	1	0	0	0	7
76	5	7	1	1	1	1	1	1	1	1	1	1	10
77	6	7	1	1	1	1	1	1	1	1	1	0	9
78	6	7	1	1	0	0	0	0	0	0	1	0	3
79	7	7	1	1	1	1	1	1	1	0	0	1	8
80	7	7	1	1	1	1	1	1	0	0	1	0	7
81	8	7	1	1	1	1	1	0	1	0	1	0	7
82	9	7	1	1	1	1	1	1	1	1	0	0	8
83	9	7	1	1	1	1	0	1	1	1	1	0	8
84	9	8	1	1	1	1	1	1	1	0	1	1	9
85	10	7	1	1	1	1	1	1	1	1	0	1	9
86	10	7	1	1	1	1	1	1	1	1	1	0	9
87	13	8	1	1	1	1	1	1	1	1	0	0	8
88	14	7	1	1	1	1	1	1	1	0	1	0	8
89	15	7	1	1	1	1	1	1	1	1	1	1	10
90	15	7	1	1	1	1	1	1	1	0	0	0	7

(F.D.: scores in the H.F.T. of the pupils (scale: 0-20), w.m.: working memory space capacity of the pupils (scale: 2-8), Pr1,Pr2,...,Pr10: problems1-10 of the mathematics test, SUM: the total score of the pupils in the mathematics test, 0: wrong answer, 1: right answer).

Data from the Second Stage of the Research

Student's No	age	sex	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	16	1	1	2	4	4	3	3	4	3	2	4	4	2	1	2	3	4	0
2	17	0	5	4	3	2	4	3	4	5	2	1	2	5	6	1	2	2	1
3	17	1	3	2	5	2	3	2	3	5	2	4	6	1	5	2	4	1	1
4	16	0	4	2	3	4	2	4	2	3	5	6	5	2	2	3	1	3	1
5	16	1	3	2	4	5	3	3	4	4	1	4	5	5	5	1	3	2	1
6	16	0	2	4	4	3	3	3	4	5	1	3	6	1	5	3	4	4	1
7	16	1	4	2	5	5	2	4	4	5	1	1	1	6	4	3	4	4	0
8	16	1	2	2	5	2	2	3	4	5	1	4	6	1	5	2	3	4	0
9	15	1	4	3	4	4	3	3	4	5	1	5	4	4	5	2	1	2	1
10	17	1	3	3	1	4	3	3	3	5	5	6	5	1	1	2	2	2	1
11	17	0	3	5	4	5	5	3	5	3	1	5	3	5	5	2	2	4	1
12	16	1	3	3	5	4	3	4	4	4	2	1	4	1	1	2	3	3	0
13	16	1	1	2	4	4	3	4	3	5	2	4	4	1	1	2	4	4	1
14	16	0	3	3	5	2	2	3	2	4	4	4	3	3	2	2	3	4	0
15	17	1	2	1	4	1	1	3	1	3	3	4	5	4	3	4	1	1	1
16	17	0	4	2	5	3	2	4	4	3	4	4	4	3	3	3	3	4	1
17	16	1	2	2	2	2	3	3	4	4	4	4	6	3	3	2	4	4	0
18	15	1	1	4	4	4	3	3	5	5	3	2	5	1	6	2	4	1	1
19	17	0	5	5	4	4	4	2	3	4	1	5	4	2	1	1	1	2	1
20	16	1	2	4	3	3	4	3	3	4	1	1	3	6	6	1	4	3	0
21	16	1	2	3	4	4	3	3	3	5	2	4	1	1	1	3	4	2	1
22	17	1	3	2	4	2	3	2	4	5	3	2	1	3	3	2	3	4	0
23	16	1	2	2	4	1	5	4	4	4	5	5	5	2	4	3	1	2	1
24	17	1	2	3	2	2	2	4	4	3	5	3	4	3	3	3	2	2	1
25	17	1	4	3	5	2	4	4	2	5	5	3	5	1	2	3	4	2	1
26	16	1	3	3	4	4	3	4	2	3	5	4	5	2	2	4	1	2	1
27	16	1	4	2	4	2	3	4	3	3	6	5	1	2	2	3	3	2	1
28	16	0	4	3	2	2	3	4	5	5	5	5	2	3	3	2	3	4	1
29	15	1	2	1	5	4	2	4	2	3	4	3	4	3	3	2	2	1	1
30	17	1	2	3	4	5	3	3	3	5	3	2	4	4	5	3	4	1	1
31	17	0	2	5	5	4	5	2	1	5	3	3	3	5	5	1	3	4	0
32	16	0	3	3	4	3	2	3	4	5	1	5	2	5	6	3	1	4	1
33	16	1	1	1	5	3	3	4	1	5	5	1	5	5	3	3	4	4	1
34	17	0	3	3	5	2	3	3	4	5	1	1	5	1	1	2	3	1	1
35	17	1	2	3	5	2	4	4	1	5	4	4	2	2	2	3	2	4	1
36	17	0	4	4	5	5	5	3	1	2	5	2	4	2	3	2	2	3	1
37	17	0	5	3	5	1	3	2	2	3	2	4	5	1	1	3	4	4	0
38	16	0	4	4	3	1	3	3	4	4	2	4	6	2	5	2	4	4	1
39	17	1	4	5	4	2	4	2	2	2	5	4	4	5	5	2	2	4	1
40	16	0	5	3	5	4	2	4	1	3	6	1	5	1	1	4	3	4	1
41	16	1	3	2	5	5	3	4	4	5	3	6	4	3	5	1	4	2	1
42	17	0	5	3	4	3	3	3	3	3	4	4	5	3	2	3	4	1	1

B 43	16	1	3	2	5	3	4	4	4	5	5	1	3	2	2	1	4	1	1
44	16	1	3	3	4	2	3	3	4	4	3	1	1	1	3	2	4	4	1
45	15	1	1	1	5	2	2	4	1	5	6	3	5	4	4	3	2	3	1
46	16	0	4	2	5	2	2	4	4	5	6	2	6	2	2	3	2	1	1
47	16	1	3	1	3	3	2	5	1	4	5	3	5	1	2	4	2	2	1
48	15	0	3	2	5	4	3	5	3	3	4	1	2	3	2	3	1	1	1
49	15	1	1	1	4	2	2	4	2	3	5	4	5	3	2	3	2	4	1
50	17	0	3	2	4	3	4	5	3	4	5	1	5	3	3	1	3	2	1
51	17	1	3	4	1	3	3	4	1	5	4	4	4	5	2	2	4	2	1
52	17	1	2	2	4	4	3	3	3	4	5	1	3	5	5	3	2	1	1
53	16	0	1	5	5	1	5	3	5	4	1	3	1	1	6	1	2	3	0
54	16	0	2	3	4	3	4	4	3	5	1	6	1	5	6	3	1	2	1
55	17	0	4	3	3	4	3	4	3	4	2	3	6	6	3	1	2	1	1
56	16	1	3	2	4	2	3	3	3	3	4	2	5	4	2	3	3	2	1
57	16	0	2	1	5	2	2	5	1	5	4	5	3	3	3	4	1	2	1
58	17	1	2	2	4	2	3	4	2	5	2	3	2	4	2	3	4	2	1
59	16	1	2	2	3	2	1	5	2	5	5	5	3	2	2	4	3	3	1
60	16	0	2	1	4	2	3	4	4	4	6	6	2	2	1	4	1	1	1
61	16	1	3	2	4	2	3	3	1	5	6	4	1	2	1	2	2	2	1
62	16	1	3	2	2	2	2	3	5	5	6	6	5	2	2	3	1	1	1
63	16	1	1	3	5	1	4	4	2	5	4	3	5	2	1	2	2	4	1
64	16	1	4	2	5	3	3	4	4	3	4	2	3	3	3	2	4	2	1
65	17	0	4	2	4	4	2	4	5	1	5	5	3	1	2	2	4	1	1
66	17	0	5	5	5	5	4	3	2	1	1	1	4	2	1	2	2	3	0
67	16	0	1	3	4	2	1	5	2	4	5	2	6	1	2	3	1	1	1
68	17	1	3	1	3	3	1	4	1	4	6	4	6	2	3	4	2	2	1
69	16	1	3	1	4	2	1	4	1	5	6	4	6	3	2	4	1	1	1
70	17	0	4	1	2	5	1	4	2	3	6	5	1	1	1	4	1	1	1
71	17	0	3	1	2	2	2	5	5	4	5	2	5	2	2	2	2	2	1
72	16	1	3	4	5	1	3	3	4	5	1	4	5	6	5	2	1	1	1
73	17	1	3	3	5	1	3	3	3	5	5	5	4	4	1	2	1	3	1
74	17	0	5	2	2	4	2	3	3	1	4	3	4	3	2	3	4	1	1
75	17	0	3	3	4	2	2	4	3	5	5	4	4	1	1	3	1	2	1
76	16	0	3	2	4	2	2	5	4	3	5	4	4	3	3	4	3	2	1
77	17	1	3	2	1	2	3	4	1	5	4	1	1	1	3	3	2	2	1
78	16	0	3	4	4	3	5	4	5	5	1	3	2	4	6	2	2	4	1
79	17	0	2	2	5	1	3	3	2	4	5	5	4	2	1	3	4	2	1
80	17	1	2	4	3	2	4	3	4	3	3	1	4	2	2	3	2	4	1
81	17	1	2	3	4	3	4	2	4	5	4	3	6	4	5	3	4	2	1
82	17	0	4	3	2	3	2	4	2	5	5	5	6	1	1	3	3	2	1
83	17	0	4	2	3	5	3	4	4	3	4	3	5	4	4	3	2	4	1
84	17	0	4	2	4	2	1	3	2	4	6	4	6	3	2	4	1	2	1
85	17	1	2	3	5	4	4	3	4	4	6	4	5	2	2	3	1	1	1
86	16	0	4	2	5	3	4	4	2	5	6	6	5	2	4	2	2	1	1
87	17	0	3	2	4	3	3	4	3	5	5	3	4	3	3	3	3	2	1
88	17	0	3	2	4	3	3	3	3	2	4	3	2	3	2	3	4	1	1
89	17	0	4	1	4	2	1	4	1	4	6	5	6	3	2	4	1	2	1
90	17	1	2	3	5	2	4	1	3	4	2	3	4	5	3	3	2	1	1

Table reading instructions follows:

Table reading instructions:

sex: 0:male, 1: female

Questions A-H: *1: strongly disagree - strongly agree: 5*

A: *You have to be clever to be good at mathematics,* ***B:*** *I do not like mathematics,* ***C:*** *You have to work very hard to be good at mathematics,* ***D:*** *I am lucky when I do well in a mathematical test,* ***E:*** *I do not think I am good at mathematics,* ***F:*** *I usually understand a new mathematical concept easily,* ***G:*** *I do not enjoy trying to solve a mathematical problem,* ***H:*** *I think that everyone should learn mathematics.*

Question I-M: *students' preferences*

I: *1: history - mathematics:6,* ***G:*** *1: geometry - algebra:6,* ***K:*** *1: chemistry - mathematics:6*

L: *1:mathematics - writing composition:6,* ***M:*** *1: mathematics - classical Greek language:6*

Question N: *I feel confident about my knowledge of mathematics, 1: never - always:4*

Questions O,P: *mother's,father's educational level, 1: university - elementary school:4*

Question Q: *motivation 1: further studying in university, 0:other.*

Appendix C

The Digits Backwards Test

DIGIT SPAN TEST

The following test, Digits Forward and Digits Backward, are administered separately. For both, say the digits at the rate of one per second, not grouped. Let the pitch of the voice drop with the last digit of each series. The series denotes the number of digits in an item.

DIGITS FORWARD

Directions – Start by saying:
'In a fairly simple game, I am going to say some numbers. Listen carefully to them, and when I stop speaking you write them down in the space provided in the sheet that you have given. Are you ready? Let us begin'.

Series:

3	5	8	9						
	6	9	4						
4	6	4	3	9					
	7	2	8	6					
5	4	2	7	3	1				
	7	5	8	3	6				
6	6	1	9	4	7	3			
	3	9	2	4	8	7			
7	5	9	1	7	4	2	8		
	4	1	7	9	3	8	6		
8	5	8	1	9	2	6	4	7	
	3	8	2	9	5	1	7	4	
9	2	7	5	8	6	2	5	8	4
	7	1	3	9	4	2	5	6	8

DIGITS BACKWARD

Directions- Start by saying:

'Now I am going to give another set of numbers, but this time there is a complication. When I have finished saying each set of numbers, I want you to write them down in reverse order. For example, if I say, '719' you would write down '917'. Now, no cheating. Do not write from right to left. You listen carefully, turn the number over in your mind and write from left to right. Have you got that? Then let's begin'.

SERIES:

2	2	4						
	5	8						
3	6	2	9					
	4	1	5					
4	3	2	7	9				
	4	9	6	8				
5	1	5	2	8	6			
	6	1	8	4	3			
6	5	3	9	4	1	8		
	7	2	4	8	5	6		
7	8	1	2	9	3	6	5	
	4	7	3	9	1	2	8	
8	9	4	3	7	6	2	5	8
	7	2	8	1	9	6	5	3

Name:
School :
Date of birth:

DIGIT FORWARD

SER	NUMBERS								
3									
4									
5									
6									
7									
8									
9									

DIGIT BACKWARD

SER	NUMBERS								
2									
3									
4									
5									
6									
7									
8									

Appendix D

The Mathematics Test

NAME:..
CLASS:..
AGE:...

Instructions:

- Read carefully the following problems
- Name the variables you are using.
- Write down the equation that you think represents best the given statement. You do not have to solve the problem.

For example:

Problem A:

Jim is holding 3 books more than Mary.
Write down the equation that represents the above statement.

Solution:

I call x: the number of books that Jim is holding (or: I call J: Jim's books)

I call y: the number of books that Mary is holding (or: I call M: Mary's books)

The equation is: $\mathbf{x = y+3}$ (or: $J = M+3$)

Problem B:
A pen costs 10p more than three times the cost of the pencil.
Write down the equation that represents the above statement.

Solution:

I call x: the cost of the pen
I call y: the cost of the pencil.

The equation is: $\mathbf{x = 3y + 10}$

Now try some yourself. If you are stuck, move on to the next one.
All the best.

Problem 1:

If Tasos raises 30p more, he will have in total 120p.

Write down the equation that represents the above statement.

Solution:

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Problem 2:

John has got £110 more than Agapi.

Write down the equation that represents the above statement.

Solution:

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Problem 3:

Manos has got 17 car cards more than football cards.

Write down the equation that represents the above statement.

Solution:

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Problem 4:
There are six times as many students as teachers in this school.
Write the equation that represents the above statement.

Solution:

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Problem 5:
Kathy has half the money she had yesterday.
Write down the equation that represents the above statement.

Solution:

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Problem 6:
Peter's father is 183cm tall. Peter wanted to know how tall he is and he climbed on a chair which was 60cm high. When her sister asked him how tall he was, he answered: "Now that I am on this chair, I am 13cm taller than dad is".
Write down the equation that represents the above statement.

Solution:

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Problem 7:

Tom's father is 5 years older than three times the age of Tom.
Write down the equation that represents the above statement.

Solution:

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Problem 8:

In a cafeteria, for every four people who take strudels, five take cheese pie.
Write down the equation that represents the above statement.

Solution:

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Problem 9:

A breeder owns cows and calves. If he sells one cow and three calves, twice per year, he raises £25 more than if he sells three cows and one calf, once a year.
Write down the equation that represents the above statement.

Solution:

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Problem 10:

Diophantu's age.

He was a child for one third of his life. After a twelfth more his cheeks were bearded. After a sixth more he got married and five years later he fathered a son. The boy died when he had reached half of his father's age. Four years later Diophantus died too.

Write down the equation that represents the above statements.

Solution:

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Appendix E

The Questionnaire of the Second Stage

University of Glasgow
Centre for Science Education

Most questions can be answered simply by putting a tick (✓) in the relevant box(es) or by writing your answer.

1. Are you: ☐ Boy ☐ Girl
2. Name:..(Please use the same name or label you have used in the other tests you participated)
3. Class: ☐ A' High ☐ B' High ☐ C' High

4. Direction of study you have already chosen or thinking about to choose:
   ☐ Theoretical Studies ☐ Science ☐ Technological Studies

5. Tick the boxes representing best your opinion.

	Strongly agree	agree	neutral	disagree	strongly disagree
You have to be clever to be good in mathematics	☐	☐	☐	☐	☐
I do not like mathematics	☐	☐	☐	☐	☐
You have to work very hard to be good in mathematics	☐	☐	☐	☐	☐
I am lucky when I do well in a mathematics test	☐	☐	☐	☐	☐
I do not think I am good in mathematics	☐	☐	☐	☐	☐
I usually understand a new mathematical idea easily	☐	☐	☐	☐	☐
I do not enjoy trying to solve a mathematical problem	☐	☐	☐	☐	☐
I think that everyone should learn mathematics	☐	☐	☐	☐	☐

6. I have partisipated at least once in a mathematical competision ☐ Yes ☐ No

7. Do you think mathematics are important? ☐ Yes Because:..
   ☐ No Because:..

*8. I like mathematics because:
   ☐ I once had a good teacher ☐ I am good at it ☐ I understand their logic
   ☐ I always liked it ☐ I take good grades ☐ Other reason:.........................

9. Tick your class preferences:
(the closest the tick to the answer, the strongest the preference)

mathematics ☐☐☐☐☐☐ history
algebra ☐☐☐☐☐☐ geometry
mathematics ☐☐☐☐☐☐ chemistry
writing composition ☐☐☐☐☐☐ mathematics
classical Greek language ☐☐☐☐☐☐ mathematics

10. I feel confident about my knowledge of mathematics: ☐ allways ☐ often ☐ rare ☐ never

11. Write your marks in the following subjects
   [.....] algebra [.....] history [.....] writing composition
   [.....] geometry [.....] chemistry [.....] classical Greek language

12. What is your parent's level of education?

	elementary school	gymnasio	lykeio	university
Mother:	☐	☐	☐	☐
Father:	☐	☐	☐	☐

*13. Where would you like to see yourself in the nearest future;
   ☐ university ☐ having a job ☐ having family
   ☐ traveling around the world ☐ I have no idea ☐ ....

* You can compete the questions with the star, with as many ticks as you wish.

Thank very much for your cooperation!

Appendix F

The Hidden Figure Test

__Notes:__

i. The F.D/F.IND tests were presented to students as an 5 booklet.

ii. Page App. F-16 formed a flap on the back of the booklet to allow students to see the Target Shapes as they searched the Complex Figures.

iii. The answers to the Shapes are included, beginning on page App. F-17.

Name:..
School:..
Age:...

SHAPES

This is a test of your ability to recognise simple SHAPES, and to pick out and trace HIDDEN SHAPES within complex patterns.

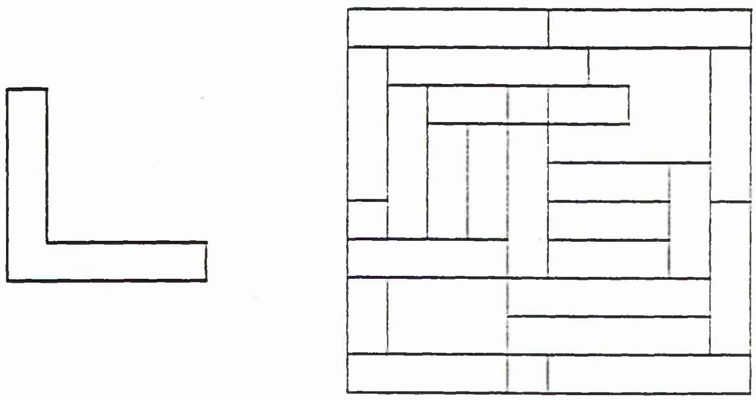
The results will not affect your course assessment in any way.

YOU ARE ALLOWED ONLY **20 MINUTES** TO ANSWER ALL THE ITEMS.
TRY TO ANSWER EVERY ITEM, BUT DON'T WORRY IF YOU CANNOT.
DO AS MUCH AS YOU CAN IN THE TIME ALLOWED.
DON'T SPEND TOO MUCH TIME ON ANY ITEM.

DO NOT START UNTIL YOU ARE TOLD

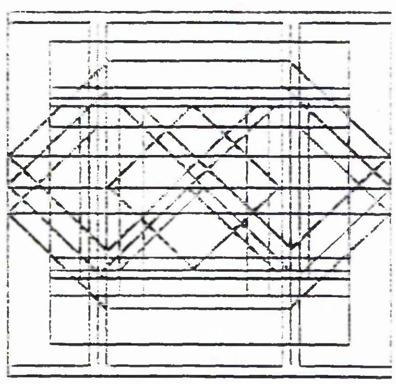
LOOKING FOR HIDDEN SHAPES

A simple geometrical 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 its 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, open out the flap on the back cover of this booklet.)

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 outine.

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.

Open out the flap on the back cover of this booklet, and you will see all the shapes you have to find, along with their corresponding code letters. Keep this page flap opened out until you have finished all the problems.

Note these points:

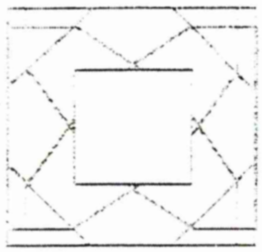
(1) You can refer to the page of simple shapes as often as necessary.

(2) When it appears within a complex pattern, the required shape is always
the same size,
has the same proportions,
and **faces in the same direction**
as when it appears alone.

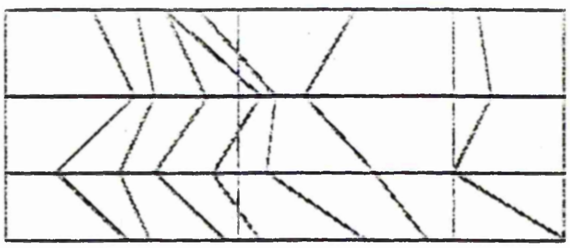
(3) Within each pattern, the shape you have to find appears only ***once.*** Trace the required shape **and only that shape** for each problem.

(4) Do the problems in order — don't skip one unless you are absolutely stuck.

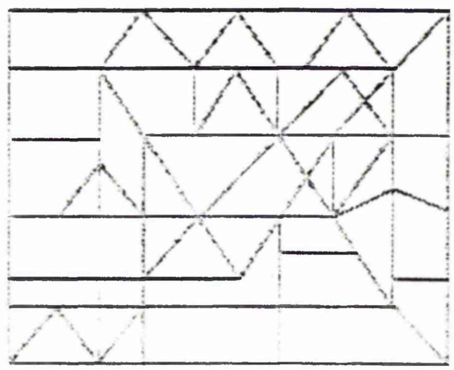
START NOW



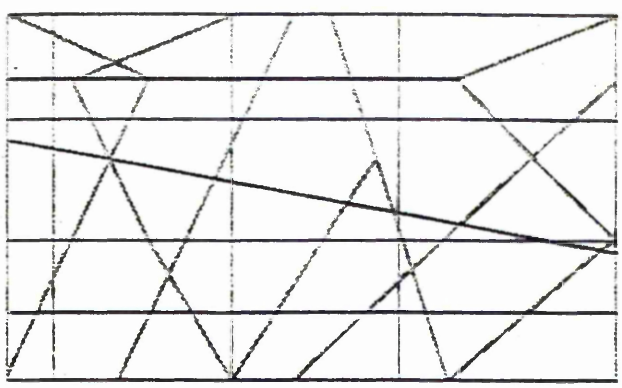
Find **SHAPE B**



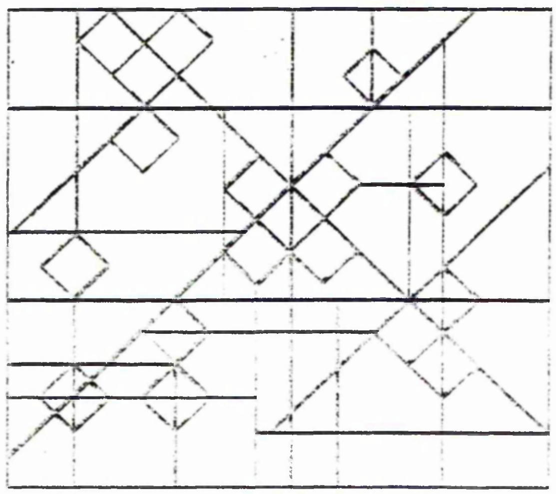
Find **SHAPE D**



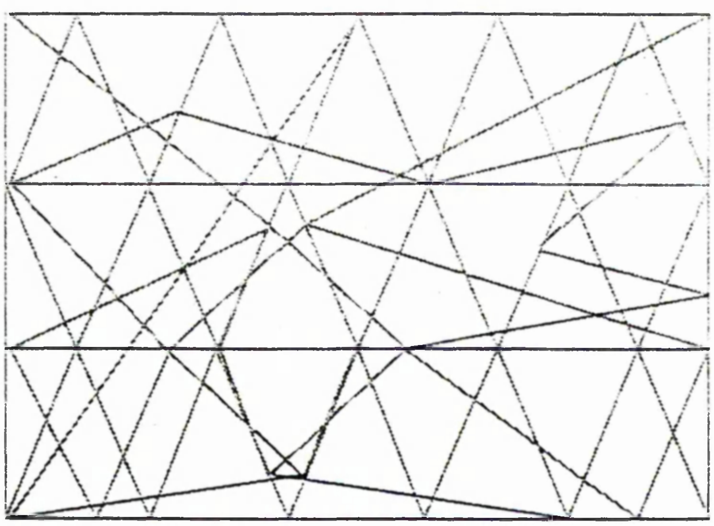
Find **SHAPE H**



Find **SHAPE E**



Find **SHAPE F**



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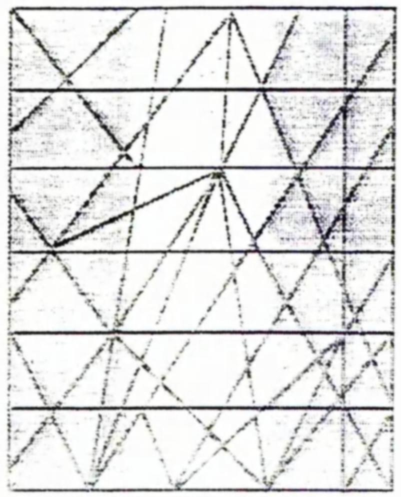

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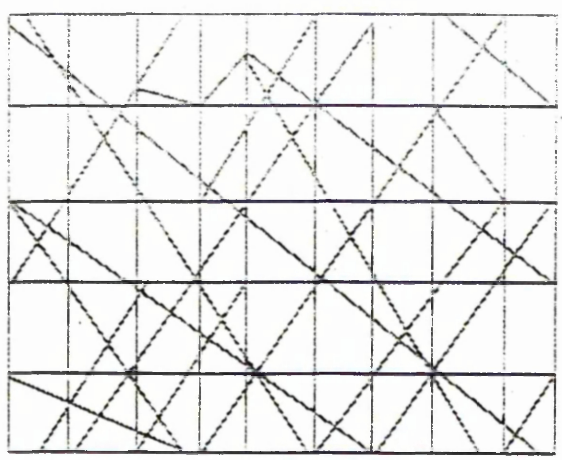

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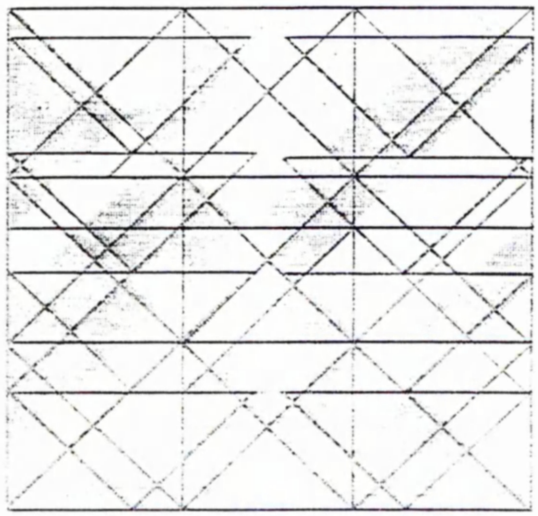

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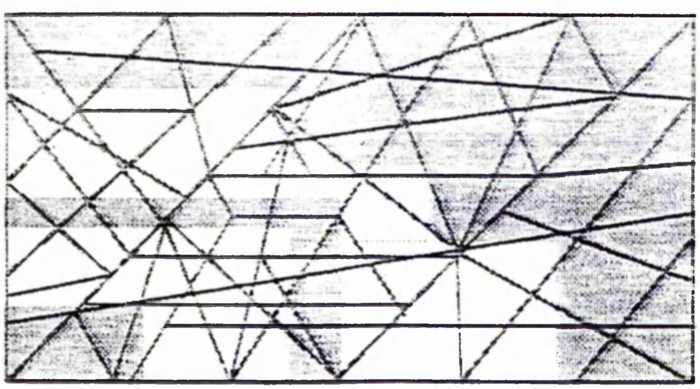
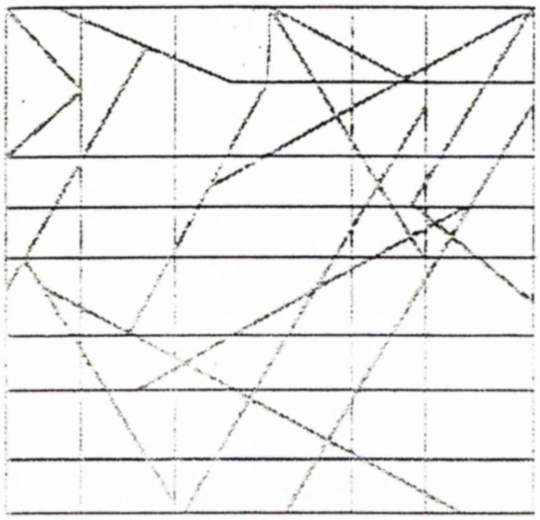
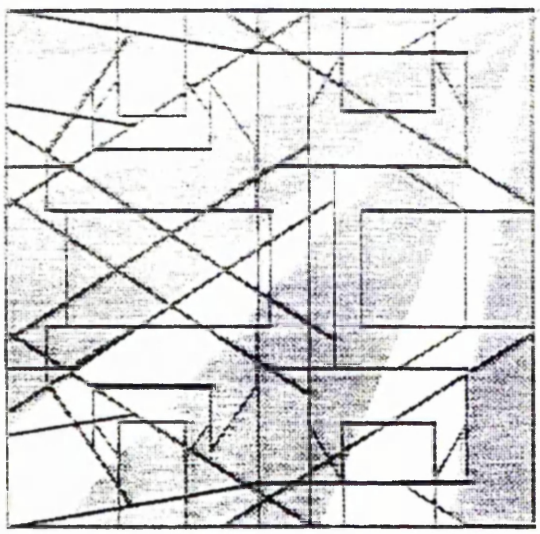


Find **SHAPE G**



Find **SHAPE C**



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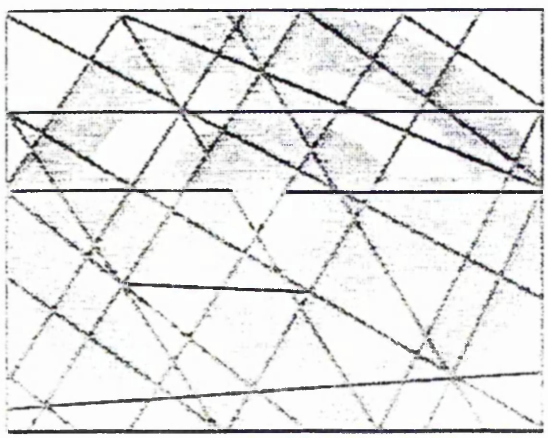

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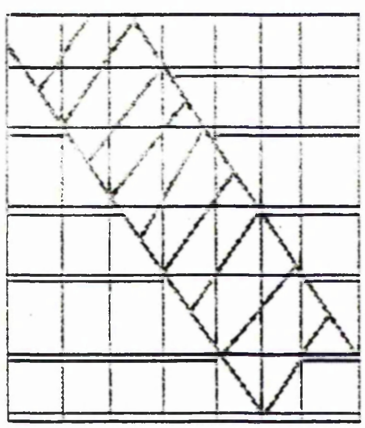

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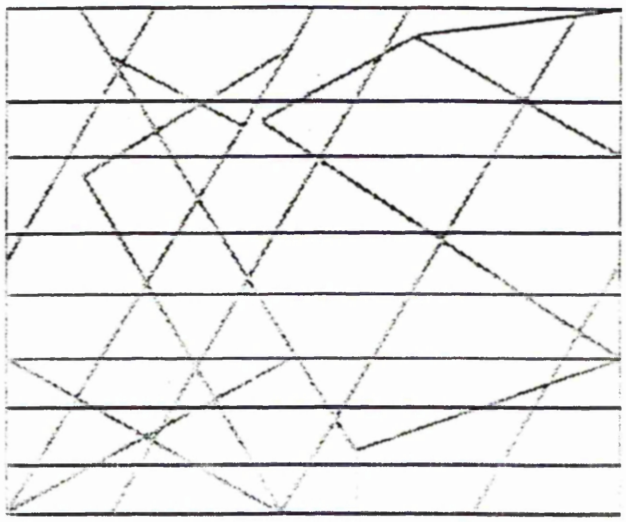

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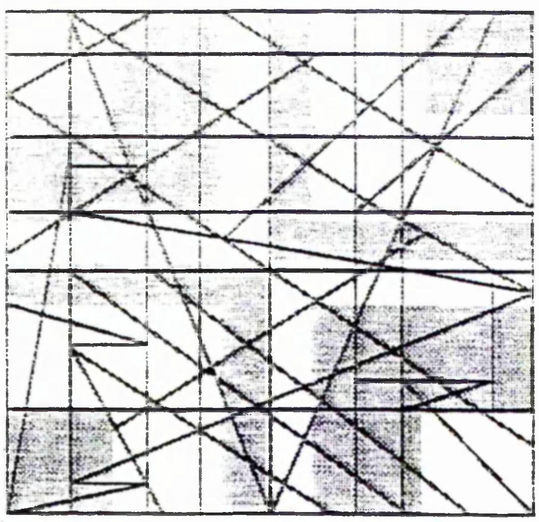

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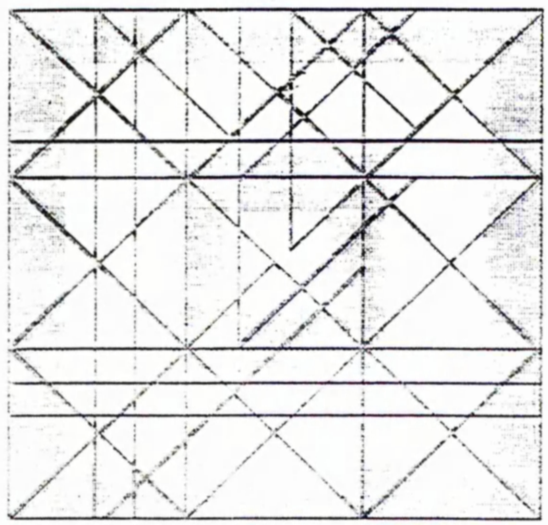

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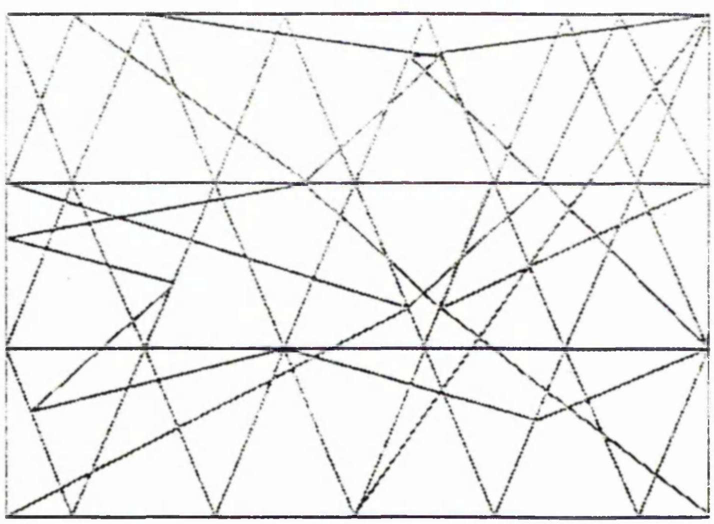

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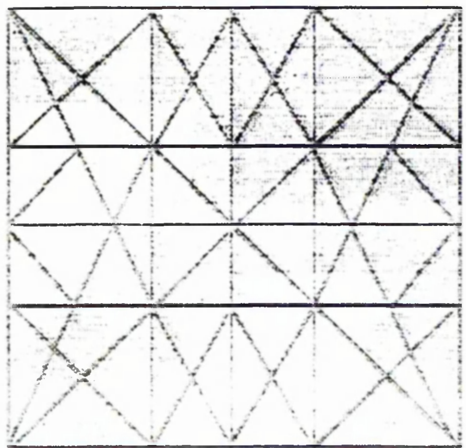
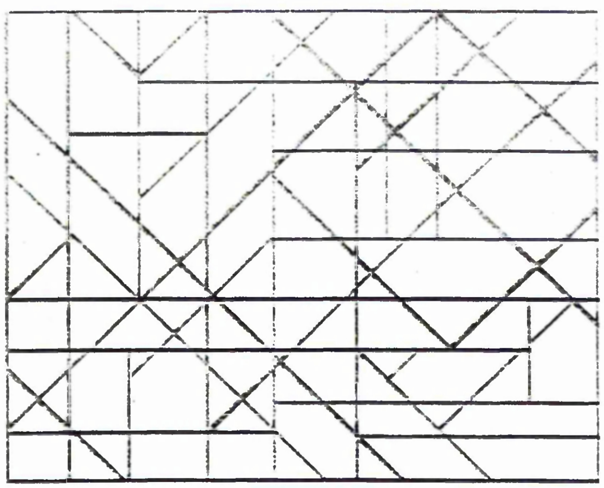


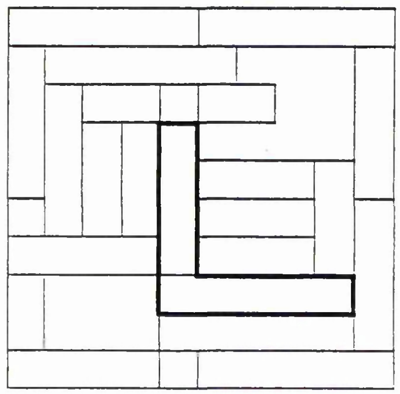
Find **SHAPE E**

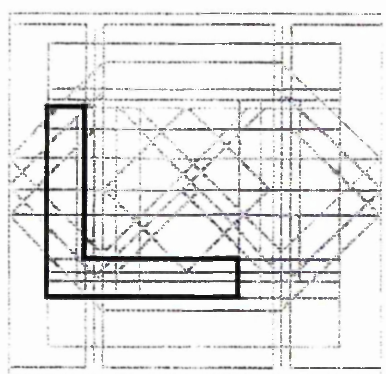


Find **SHAPE F**

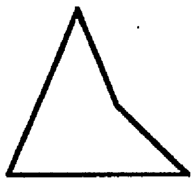
ANSWERS

When you have traced both L-shaped figures, the diagrams should look like this :

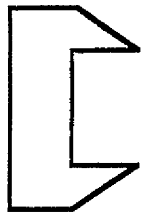




THE SHAPES YOU HAVE TO FIND



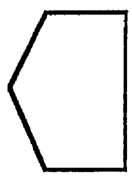
A



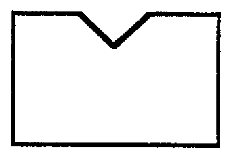
B

C

D



E

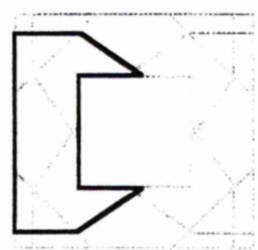


F

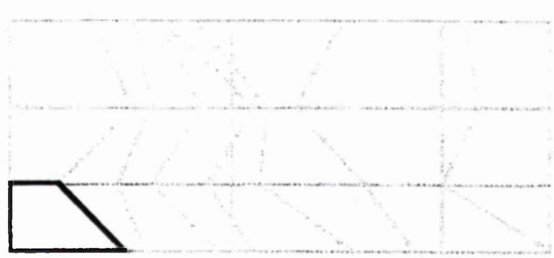
G

H

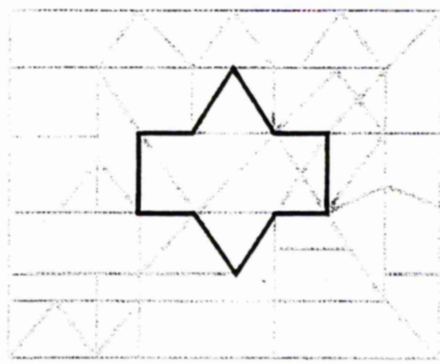
ANSWERS TO SHAPES



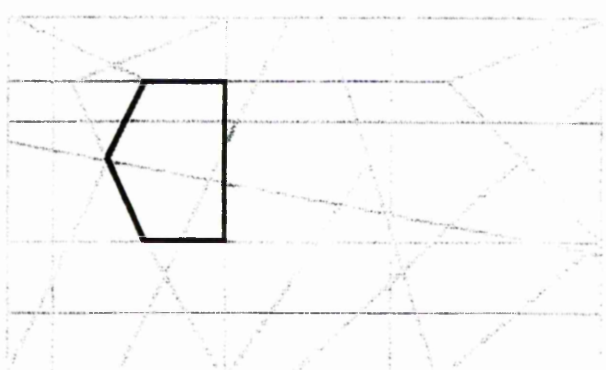
Find **SHAPE B**



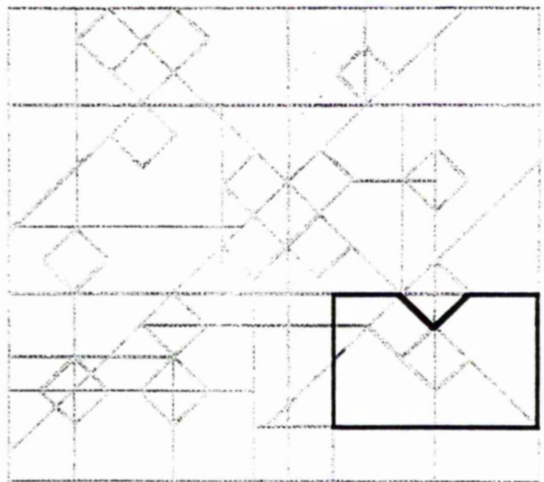
Find **SHAPE D**



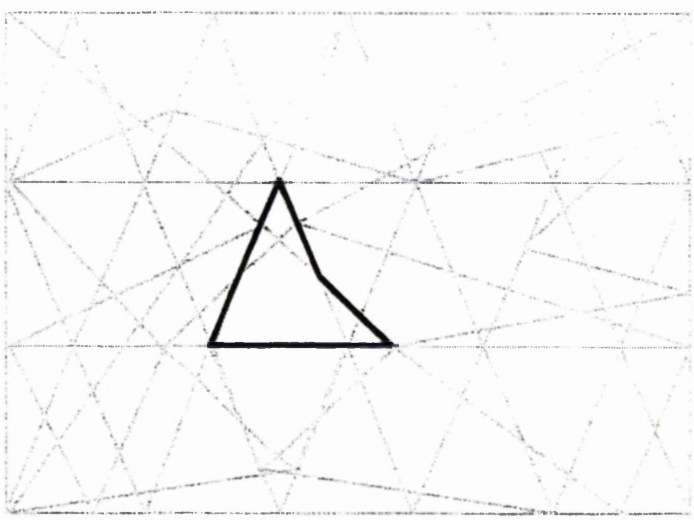
Find **SHAPE H**



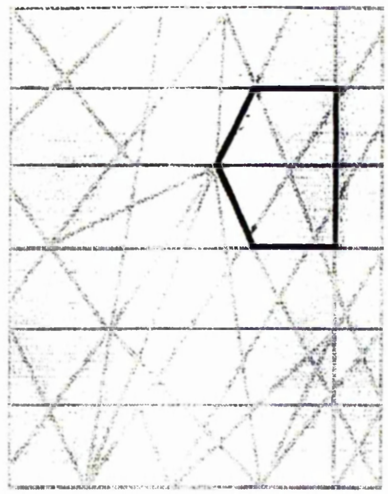
Find **SHAPE E**



Find **SHAPE F**



Find **SHAPE A**



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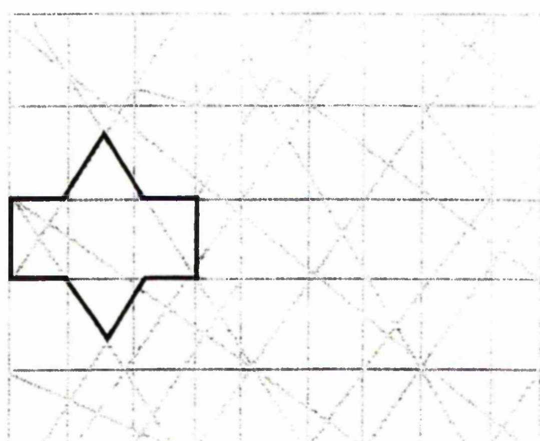

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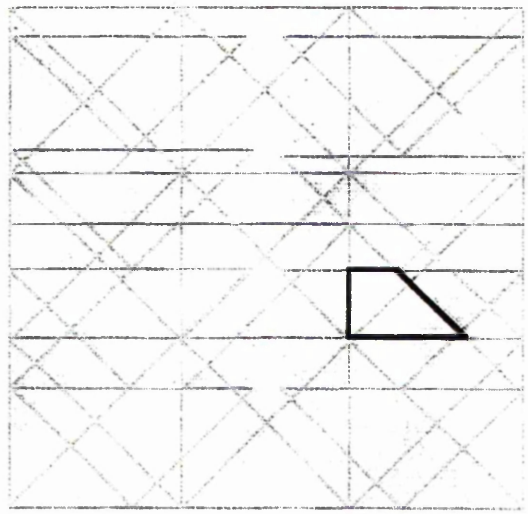
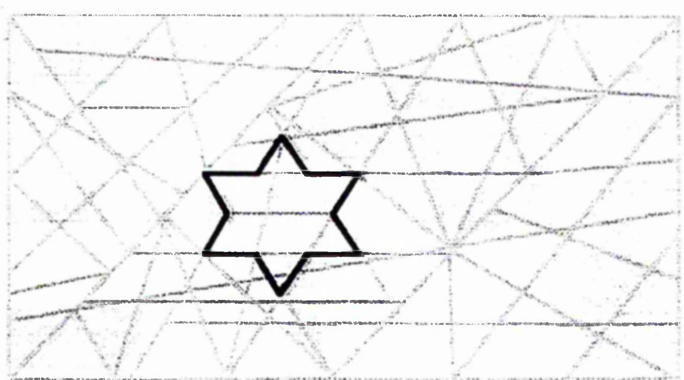
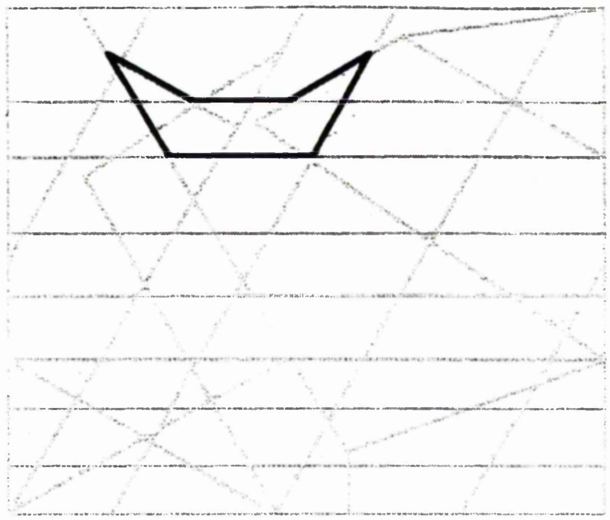


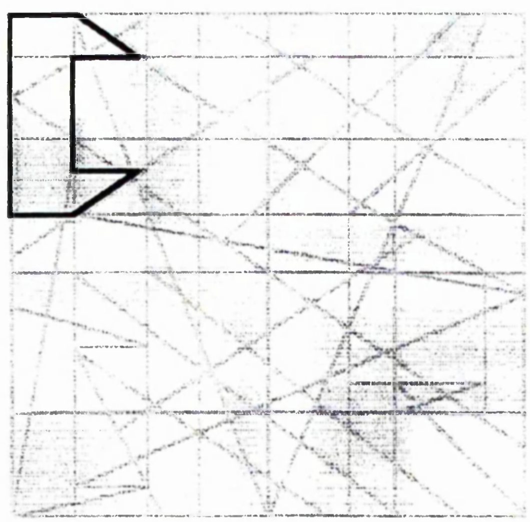
Find **SHAPE D**



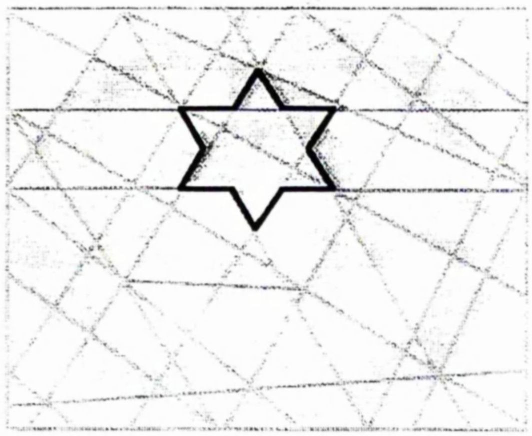
Find **SHAPE G**



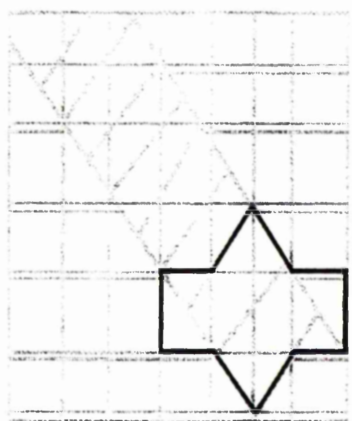
Find **SHAPE C**



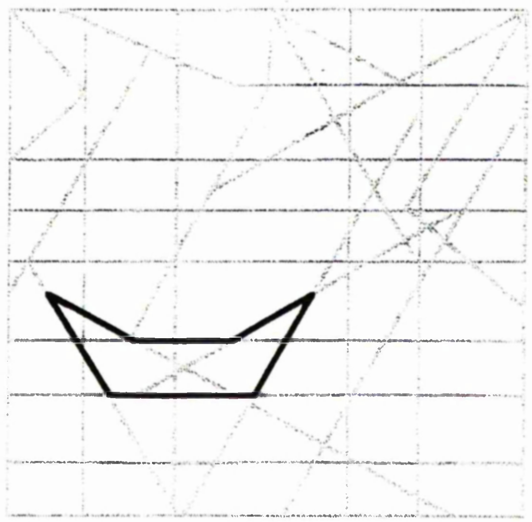
Find **SHAPE B**



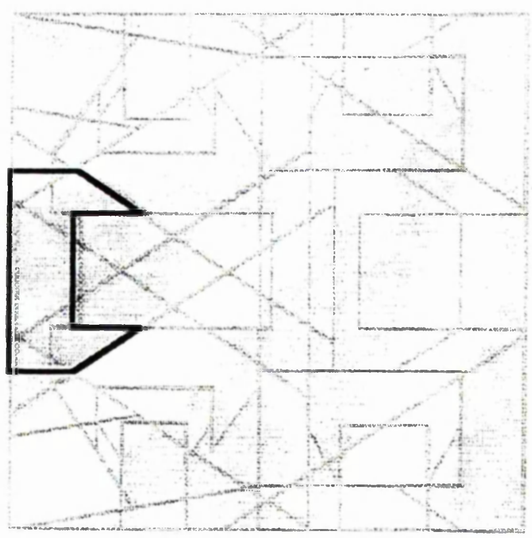
Find **SHAPE G**



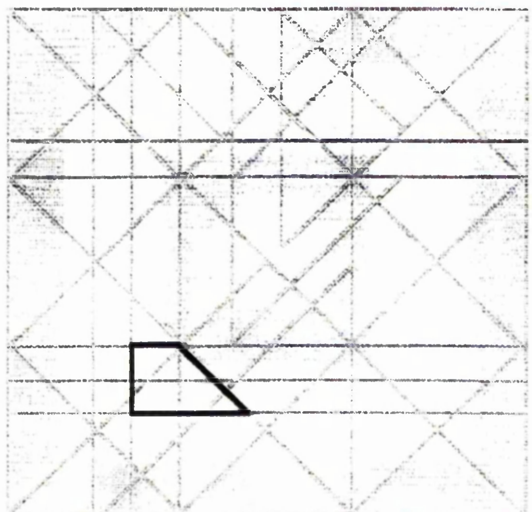
Find **SHAPE H**



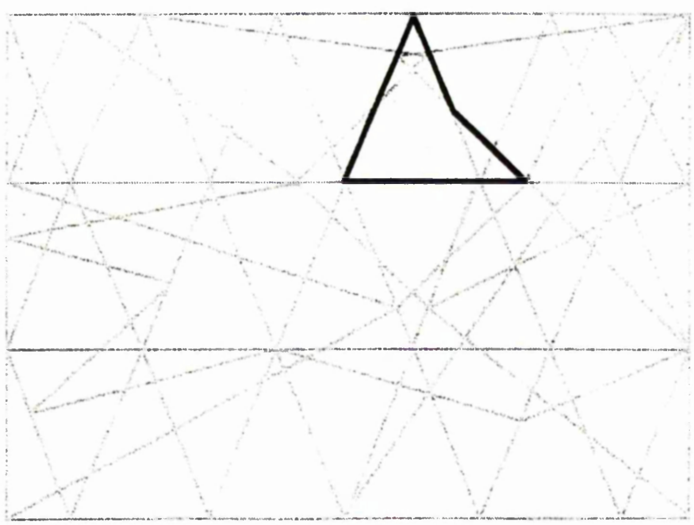
Find **SHAPE C**



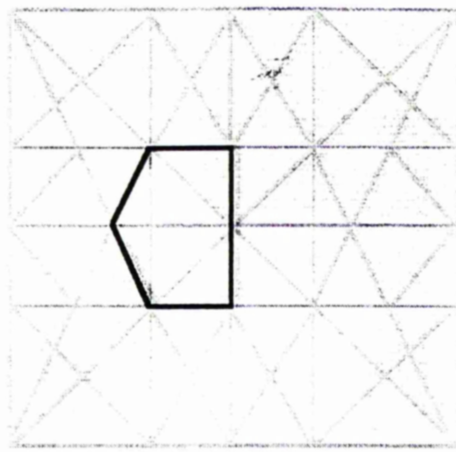
Find **SHAPE B**



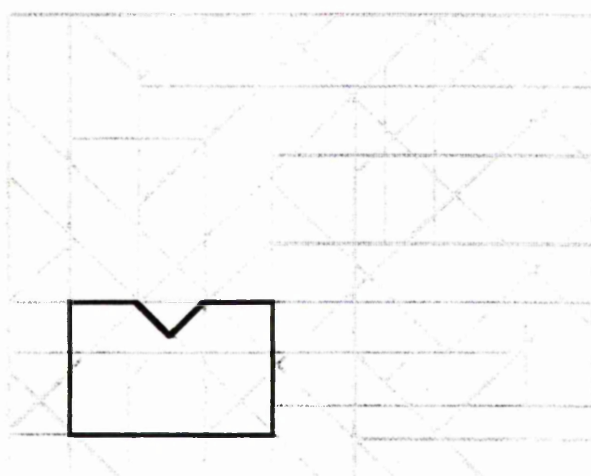
Find **SHAPE D**



Find **SHAPE A**



Find **SHAPE E**



Find **SHAPE F**