# Attitudes and Learning Difficulties in Middle School Science in South Korea


**By**

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# Abstract

The purpose of this study is to investigate the relationship between cognitive and attitudinal aspects of learning science, concentrating mainly on the influence of cognitive understanding and learning difficulty on attitudes to science. This theme is selected, in particular, because it is reported that Korean students at secondary level do not enjoy studying science and have not enough confidence, although their achievements are high.

Johnstone's information processing model (1993) is used to account for cognitive aspects of science education. Learning processes are understood in terms of student's own knowledge construction through the operation of perception filters, processing in working memory space and storing in long term memory. In particular, the overload of student's working memory space is considered as the main factor causing learning difficulty and, in consequence, learning failure.

The research took place in one middle school located in Seoul, the capital city in South Korea. 364 students aged 13 and 350 aged 15 participated. In order to try to find relationships between cognitive and affective factors of science learning, individual student's working memory space was measured and a questionnaire designed to gather information about students' attitudes was prepared and given to all students. To determine the working memory space capacity of the students, the Figural Intersection Test (F.I.T), designed by Pascual-Leone, was used.

Two kinds of analysis, comparison and correlation, were performed with data from the Figural Intersection Test and the questionnaire applied to students. For the comparison of attitudes between age 13 and 15, the distributions of frequencies of responses were analyzed for each particular statement in a question. The Chi-square ($\chi^2$) test was applied to judge the statistically significant differences in responses of the two groups. The levels of significance used were 0.05, 0.01 and 0.001.

In order to see whether there is difference of opinions related to various aspects of learning science between age 13 and 15, and between high and middle and low working memory capacity groups, students responses were compared by just looking at the distribution of percentages without doing more statistics. Correlation coefficients were calculated to see if student's working memory capacity is linked with attitudes.

As a result of data analyses from the working memory test and the questionnaire, it is seen that working memory space is related to some student attitudes towards science and their way of studying. Compared to students with high working memory capacity, students who have low working memory capacity are likely to lose their interest in science, feel science is difficult, and have low confidence about studying science. In addition, they tend to depend on memorization when they study science, consider science as a future career less, and are less motivated to study science by attitudinal factors such as "I really enjoy studying science", "Science is useful in my life".

This exploratory study has suggested some important issues which need addressed in developing positive attitudes as well as encouraging meaningful learning.

# Contents

# List of figures

# List of Tables

# Chapter One

# Introduction

Every educational activity has its objectives. The educators want to bring about or produce something in learners. They want their learners to make sense of something. They wish to make learners acquire some skill. They wish to improve or perfect their learners in one sense or another. In other words, objectives are "explicit formulations of the ways in which students are expected to be changed by the educative process" (Bloom *et al*, 1956). Therefore the first work of curriculum developers is deciding objectives when they set up a new curriculum. Many school textbooks display objectives in the introduction.

Stated objectives can do four things (Johnstone, 1975):

- The teacher is given a clear picture of the change in behaviour expected in the learner.
- The learner is also given a clear picture of where he is meant to get to during the educational process.
- The teacher is enabled to assess critically whether the teaching means are appropriate to his objectives.
- The teacher is enabled to consider the most appropriate form of assessment.

Indeed, what objectives teachers select for students is very important because all teaching processes depend on the objectives. Teachers prepare teaching materials, provide activities and experiences, create learning environments, and encourage students' behaviour and performance in accordance with the objectives.

## 1.1 Cognitive and Affective Domains of Educational Objectives

According to the most widely accepted taxonomies of educational objectives (Bloom *et al*, 1956; Krathwohl, Bloom, and Masia, 1964; Simpson, 1966), educational objectives are separated into cognitive, affective and psychomotor domains. The cognitive domain deals with the process of knowing and the development of intellectual abilities and skills. The affective domain deals with influences of feeling, values, and beliefs on one's behaviour. The psychomotor domain deals with developing physical actions, abilities and skills (Hauenstein, 1998). The cognitive domain has six major categories of objectives. The affective domain has five major categories. The psychomotor domain ranges from five to seven major categories according to the writer. (see table 1.1)

| Lowest ← | | | Levels | | → | Highest |
|---|---|---|---|---|---|---|
| 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | 6.00 | 7.00 |
| **Cognitive Domain Categories (Bloom et al.1956)** | | | | | | |
| Knowledge | Comprehension | Application | Analysis | Synthesis | Evaluation | |
| **Affective Domain Categories (Krathwohl et al. 1964)** | | | | | | |
| Receiving | Responding | Valuing | Organization | Characterization | | |
| **Psychomotor Domain Categories** | | | | | | |
| Perception | Set | Guided response | Mechanism | Complex overt response | Adaptation | origination |
| (Simpson 1966) | | | | | | |
| Imitation | Manipulation | Precision | Articulation | Naturalization | | |
| (Dave 1970) | | | | | | |
| Familiarization | Fundamentals | Development | Adjusting & adapting | Perfection & maintenance | | |
| (Harrow 1972) | | | | | | |
| Perceiving | Imitating | Manipulating | Performing | Perfecting | | |
| (Hauenstein 1972) | | | | | | |

**Table 1.1 Taxonomies of Educational Objectives**

*(From Hauenstein, 1998)*

Among these three domains, the cognitive and affective domains have attracted much attention with science educators. School science education has emphasized cognitive growth and measurement although many science curriculum developers valued the enhancement of students' interest and stressed affective objectives very early (PSSC, 1960; Haber-Schaim, 1969; Dowdeswell, 1967). However, the resources, textbooks, equipment and teacher training, have been concentrated on achieving cognitive objectives. Reid (1978) suggested possible reasons for this. Firstly, many of the teachers at secondary or tertiary levels are deeply suspicious of all attempts to look beyond the content of their subject specialism. Affective developments are thought to be irrelevant or impossible and beyond the province of the school. Secondly, affective assessment is difficult and open to criticism and only what is examinable tends to be taught in the school situation. Lastly, appropriate approaches to the development of attitudes have not been developed very much. Without suitable materials, teachers cannot have confidence in developing students' attitudes.

It appears that affective objectives are incompatible with cognitive objectives mainly from the teachers' point of view. However, is it really difficult or impossible to accomplish both cognitive and affective objectives at the same time? The work of this thesis began with this question and attempts to make a practical suggestion for students' cognitive and affective development.

## 1.2 The Aims of This Research

What is, indeed, the greatest concern of science educators at the present time? One candidate must be students' increasing alienation from science. The science teacher's job satisfaction is likely to be strongly influenced by their students' affective responses more than by their cognitive responses. One of the motivations that make teachers revise and alter their teaching method and topics is the intention to increase their students' engagement with science and interest in studying science subjects. The issue of attitudes is also of direct concern to others in science community (Ramsden, 1998). Many recent curriculum developments have been suggested for making science more attractive to students as an area of study (e.g. *Science in process*, Wray *et al*, 1987; *Science: the Salters' approach*, University of York Science Education Group, 1990-1992; *ChemComm*, American Chemical Society, 1988; *PLON*, Dutch Physics Curriculum Development Project, 1988).

However, there are few satisfactory and widely agreed solutions to this problem in spite of the recognition of the important of attitudes. On the other hand, we cannot concentrate only on attitudes. Although we aim for attitude growth, it must be accomplished through the content of science curriculum. Interest in science and acquisition of scientific comprehension cannot be separated.

The aim of this research, therefore, is to investigate the relationship between cognitive and attitudinal aspect of learning science, concentrating mainly on the influence of cognitive understanding and learning difficulty on attitudes to science.

## 1.3 The Structure of This Research

This study attempts to find how much certain cognitive aspects of learning correlate with attitudinal aspects. This thesis has the following structure:

- In chapter two, the South Korean education system is described with its social background and then the current problems in science education are examined.

- In chapter three, science education is examined in terms of its cognitive aspects and an information processing model is introduced in order to understand the learning process. The overload of students' working memory space is considered as the main factor causing learning difficulty and, in consequence, learning failure.

- In chapter four, the matter of attitudes is considered. Definitions of attitude, the process of attitude formation and change, and especially attitude development in the context of science education are discussed.

- In chapter five, it is attempted to bring cognitive and attitudinal aspects of learning science together in thinking about science education. Several guiding principles are suggested in relation to development of desirable and well-informed attitudes connected with the school science education.

- Chapter six describes the way the present study was carried out. The extent of research, the research questions, and the methods of data collecting and analyses are discussed.

- Chapter seven describes students' attitudes towards studies in science and the scientist, students' self-perception in studying science, and students' general views about various aspects of learning science on the basis of questionnaire analysis.

- Chapter eight shows the results of investigation into the correlation between working memory space and attitudes. Comparison between students with high, middle and low working memory capacity and their interest in science, their way of learning, and their reasons for studying science is also considered.

- Finally, chapter nine draws the conclusions and makes suggestions for teaching and further research on the basis of the results from the above studies.

# Chapter Two

# The South Korean Education System

This chapter describes the South Korean education system along with its social background and then examines current problems in science education. It provides the context for this research and describes the reasons why it has been done.

## 2.1 Social Background of the Korean Education System

Korea underwent Japanese colonial rule for 36 years at the beginning of 20$^{th}$ century and became an independent country in 1945 with the end of the Second World War. However, Korea soon faced national division into the Northern half and the Southern half by the Western Powers, and both North and South Korea were under the military occupation of the Soviet Union and the U.S.A., respectively. This led to the terrible Korean War 5 years later. It ended with the 1953 armistice. However, the hostile forces are still deployed along the 155-mile demilitarized zone (DMZ).

As a result of the Japanese occupation and the Korean War, the South Korean economy was completely destroyed. In addition, with a small area (99,500sq.km) and poor natural resources, South Korea had to develop its economy from an extremely poor base and only human resources and peoples' diligence became the driving force for its economic growth. "If we do, we can do" was a main slogan at that time. During the 1970s and 1980s, a great deal of progress was made by the South Korean economy thanks largely to the government-led five-year economic development plans implemented since the early 1960s. However, the development of politics and education was far behind when compared to economic development common in developing countries.

On the other hand, under the circumstances that depend only on human ability without any useful natural resource to develop the country, the Korean people came to believe that national competitiveness depends on human resources development and that the level of skill and education is the major source of trained manpower in the various fields. Therefore, hard work was seen as the best way to succeed and this meant a good academic standard became a symbol of competence and success from an individual standpoint. Consequently, almost all parents want their children to go to a good university which guarantees a promising career, and this situation produced great concern about educational matters and the trend that parents should do their best for their children's studying and the goal of studying is university entrance. This tendency led to an increase in the use of private "crammers" (called 'hakwon') after school hours and private lessons at home. According to an article in one daily paper, 72.6% of students take such extra lessons (Joong-ang Daily News, October 20, 2003).

In 1997, Korea experienced a serious economic crisis (what we call IMF) and this forced many companies to go into bankruptcy and produced a great number of unemployed people. Afterwards, seeking a job and job security became a main concern among young people. In consequence, the public interest, which considered education as a way to enter several prospective occupations such as lawyer and doctor, has been strengthened, through the educational authority, the Ministry of Education & Human Resource Development, has sought to cultivate the well-educated person with personality and creativity. This is seen to lead to the knowledge-information society of the twenty-first century through education that fosters student's talents and aptitude.

## 2.2 The Structure of Korean Education System

The main track of the Korean education system includes six years of elementary school, three years of middle school, three years of high school and four years of university education. Children start to go to school at the age of six and receive 9 years compulsory education at elementary and middle school the aim of which is to conduct standard elementary and secondary education. There is no special examination to enter high school and most pupils (99.7%, 2003) continue to be educated at high school and the majority attend general high schools. In addition, there are several specialized high schools such as commercial, technical, and science high schools for students who decide their career path at an early stage. It is necessary to participate in the College Scholastic Ability Test (CAST) at the third year of high school in order to enter university. The CAST consists of five areas: language, mathematics, English, Social Studies/Sciences/Vocational Education, Foreign language/Chinese Characters and Classics. Students can select tests and subjects in terms of their needs, learning abilities and career goals (see figure 2.1).

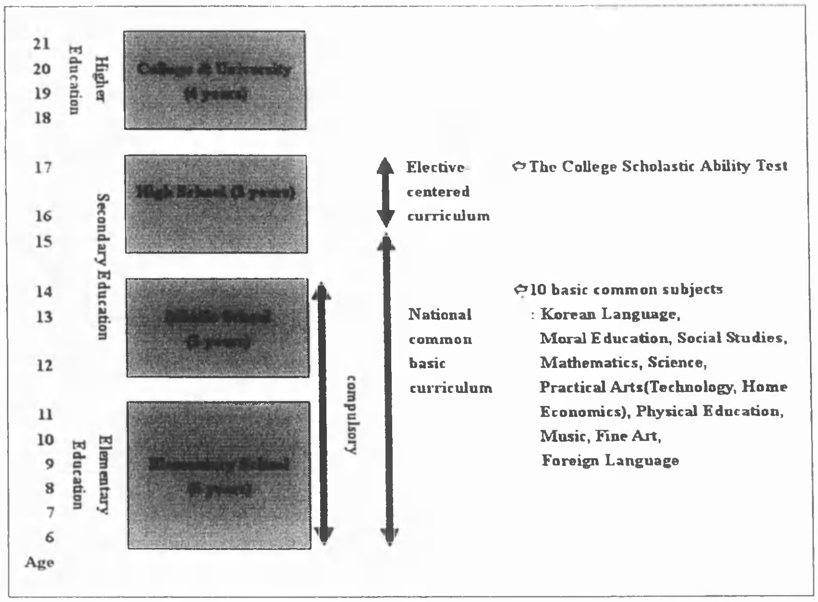



**Figure 2.1 The South Korean Education System**

To ensure the standard quality for education, Education Law 155 prescribes the curriculum for each school level and the criteria for the development of textbooks and instructional materials. According to this, the Ministry of Education & Human Resource Development promulgates the national school curriculum. The seventh national school curriculum, revised 1997, introduces 10 basic common subjects, autonomous activities and special activities that cover the ten years from the first year of elementary school through the first year of high school and elective subjects for the final two years of high school. These are designed to provide student choice in consideration of individual differences in career desire and aptitude.

Science subjects are introduced in the third year of elementary school and pupils are taught general science, which comprises energy, matter, life, earth, investigation and environment until first year of high school. In the second year of high school, the science subject is divided into four fields, that is, physics, chemistry, biology and earth science and pupils can choose their subject according to their aptitude and path in life. There are also science high schools, which were established in response to a sudden rise of concern for providing good places for the education of youngsters with scientific talent and the nation's paramount interest in advancing scientific and technological discovery. The first science high school was established in 1983 with the purpose of providing scientifically gifted children with a consistent and systematic program in order to develop their potential at an earlier stage. At present, there are 16 science high schools throughout the nation. Those who have completed two years in a science high school can be admitted to the bachelor's program at the Korea Advanced Institute for Science and Technology.

## 2.3 Current Issues in Science Education

One of the main anxieties in science education at present is that the number of students who choose a science track and enrolments in science and technology courses at university are decreasing rapidly. The rate of applicants for science direction in CAST decreased from 34.6% in 2000, 29.4% in 2001 to 26.9% in 2002 (News Release of The Korea Institute of Curriculum & Evaluation, June 30, 2001, December 14, 2001).

Surprisingly, it can be seen from the results of the TIMSS (Trend in International Mathematics and Science Study) 2003 survey that Korean eighth-graders (second year of middle school) ranked third place among the 45 participating countries in science. It means that the performance of Korea eighth-graders in science was higher in 2003 than it was in 1999 (fifth place among the 38 participating countries, News Release of The Korea Institute of Curriculum & Evaluation, December 15, 2004). However, the Korean students' scores in confidence and enjoyment of science were below the international average. It is thought that good performance might be not followed by positive attitude from these results.

In 2002, the government established a nation-wide 'science education development plan focusing on investigation and laboratory' (News Release of Ministry of Education & Human Resource Development, December 6, 2002). This was based on the idea that investigation and laboratory-based science class teaching is the key point to promote students' interest in science and develop science-technology manpower. It was decided to invest about 200 million dollars for five years from 2003. The core assignments are as follows:

- Modernization of science laboratory roomd and expansion of science teaching tools.
- Expansion of support materials and circumstances for investigation and laboratory teaching and learning.
- Development of science teacher's laboratory teaching capability.
- Raising of adolescents' scientific thought.
- Improvement of science teaching and establishment of a support system.

However, although this plan seems impressive, it may fall short of success if it does not bring about a change of student's attitude towards science.

In conclusion, it is clear that Korea needs highly qualified human resource in the science and technology field for economic and industrial development. However, it is true that the current science education has failed to make younger generation interested in science. Behind this observation, there is the problem of an education system, which is focused very strongly on university entrance examinations and a social atmosphere aimed at achievement. Therefore, the prosperity of Korea depends on how to resolve these problems.

# Chapter Three

# Information Processing Model

Many people (e.g. Atkinson and Siffrin, 1971; Sanford, 1985; Child, 1993) proposed information processing models of learning. Among them, the model introduced by Johnstone (1993) is a product of the educational movement in the latter half of the 20$^{th}$ century. During that time, a number of people started to see education from a learner's point of view. Therefore, much attention was paid to the learner and the processes of human learning. In the background of this shift in thinking, there are constructivistic theories. Piaget (1896-1980) considered the connections between age and the complexity of thinking. According to his model, all children develop their cognitive structure through four stages: sensorimotor, preoperational, concrete-operational and formal-operational (Flavell *et al*, 2002). On the other hand, Ausubel placed emphasis on the learner's prior knowledge and also insisted that every student constructs his own knowledge in his own way (Ausubel, 1968). In other words, a concept has to be reconstructed when it passes from the head of the teacher to the head of the student.

However, the factor that makes Johnstone's information processing model more significant and practical is its concern about learning limitations being followed by learning difficulties. A careful investigation of that model might provide the answer of questions such as where the limitations come from and how to help students to overcome the difficulties. The model was based on a vast accumulation of empirical evidence and offers insights and predictions into all aspects of learning.

## 3.1 Mechanism of Learning

According to the information processing model, the information which we receive from external environments is mediated by a perception filter, processed in working memory space and stored in long term memory. The flow of information during learning can be seen in Figure 3.1.

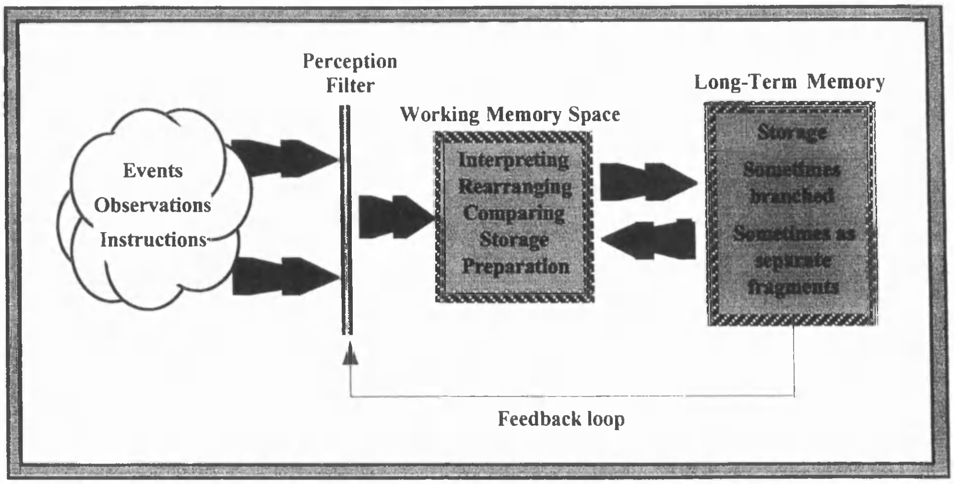



**Figure 3.1 The Information Processing Model**

*(From Johnstone, 1993)*

## 3.2 Perception Filter

In all situations, a huge amount of information is received from outside through senses such as sight and hearing. However, people also have a filtering system (perception filter) that enables them to neglect external phenomena which are not important to them and attend to what they think matters. In other words, the learner selects information which is important, interesting and understandable through this filtering process and only those pieces of information which are selected can be processed further in the learner's brain.

The important characteristic of human perception is its strong dependence on what people already have in their long term memory (see the feedback loop between the perception filter and the long term memory in figure 3.1). According to Johnstone (1997), "*the perception filter must be driven by what we already know and understand. Our previous knowledge, biases, prejudices, preferences, likes and dislikes and beliefs must all play a part.*" Indeed, what is selected by a learner is affected by his/hers previous knowledge, attitudes and abilities. Moreover, we also use our experience, knowledge, even wrong knowledge, when we interpret incomplete sensory information and give it more meaning.

In conclusion, a learner's decision to act on new information is vital in learning. Importantly, the activation and control of perception filter takes place in an idiosyncratic way because every learner has a unique set of held knowledge and beliefs.

### 3.3 Working Memory

Once we admit new information through the perception filter, it goes to the working memory where the manipulation takes place. Johnstone (1984) defined working memory as "*that part of the brain where we hold information, work upon it, organize it and shape it before storing it in long term memory for further use.*" Working memory holds selected information and processes it through the operations such as interpreting, rearranging, comparing and storage preparing in order to make sense. It interacts with not only prior knowledge which is stored in long term memory but also the perception filter for receiving and responding to incoming information.

There are important attributes of working memory space and Johnstone described these:

> *"The working space has two main functions. 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 filter consciously interacts with itself and with information drawn from long-term memory store in order to "make sense." However, there is a drawback. This working space is of limited capacity…. It is a limited shared space in which there is a tradeoff 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 is required, we cannot store much."*
>
> (Johnstone, 1997)

The capacity of the working memory depends on the age of individual and it is known to grow on average by 1 unit for each two years until about age 16. A 'unit' is what is perceived as one item of information by the individual person. It is found that, in general, adults have $7\pm2$ units (Miller, 1956). Furthermore, it cannot be increased. However, there is the possibility for a learner to use it more efficiently. One way of achieving this is known as 'chunking'. Chunking is a process by which information can be grouped, thus enabling more to be held in working memory. For example, H-O-R-S-E occupies five bits of space for the children who just start to learn reading. However, if children come to recognize it as one word HORSE, it uses only one bit of space. The more information students can make into recognizable group by means of chunking, the more complicated ideas they are able to handle at one time.

Chunking is controlled by a student's previous knowledge, experience and acquired skills (Johnstone and El-banna, 1989). Therefore, the student's way of chunking as a novice is different from the teacher's way as an expert. The teacher has a well-organized knowledge network in the brain and has developed many chunking skills through his or her learning and teaching experience. However, the student does not necessarily have enough knowledge and experience to develop a good chunking strategy. For this reason, the student's working memory space is easily overloaded in a learning situation and this can cause learning difficulty. This will be considered later in more detail.

To sum up, working memory is the limited, shared space in which new ideas are held and processed. It interacts with long term memory and there is continuous interchange of information between them. Processed material in the working memory space is passed to the long term memory store for safekeeping and, at the same time, material can be recalled from the long term store to help with the processing in working space (Johnstone, 1997). These processes are memorization and recall. The important feature to recognize is that working memory is where the person thinks and problem solves. It has limited capacity and is, therefore, a major limiting factor in all learning.

### 3.4 Storage and Recall

For the purpose of storage, the memory uses a variety of functions: pattern recognition, rehearsal, elaborating and organization. This process is personal. Every learner reconstructs material provided by teacher using available knowledge, beliefs, biases and misunderstanding in long term memory.

According to Johnstone (1997), there are four ways of storing:

- *"The new knowledge finds a good fit to existing knowledge and is merged to enrich the existing knowledge and understanding (correctly filed).*
- *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).*
- *Storage can often have a linear sequence built into it, and that may be the sequence in which things were taught.*
- *The last type of memorization is that which occurs when the learner can find no connection which to attach the new knowledge."*

Ausubel *et al* (1978) offered a useful insight when he grouped learning into two classes; meaningful learning and rote learning. The first way of storing is called meaningful learning because new knowledge is linked to appropriate old knowledge and understanding. On the other hand, the last way is labeled rote learning, in which there is no interaction between new knowledge and old knowledge. Meaningful learning is easy to retrieve and almost never lost, whereas rote learning is very likely to be lost and very hard to retrieve.

## 3.5 Long Term Memory

Long term memory is a large store where facts are kept, concepts are developed and attitudes are formed (Johnstone *et al.*, 1994). It is the ultimate destination for information a person wants to learn and remember and the memory system responsible for storing information on a relatively permanent basis (Ashcraft. 1994). Its capacity seems to be limitless and its duration virtually endless (Solso, 1995).

The most important attribute of long term memory in terms of learning is its linkage with the perception filter and the working memory. According to Johnstone's information processing model (1993), the long term memory controls perception and provides information for working memory. 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)

## 3.6 Working Memory Overload and Learning Difficulty

It was mentioned that the student's working memory is easily overloaded in a learning situation because the working memory is severely limited in size and the student's chunking skills are not yet developed enough to reduce the load of information on the working memory. Particularly, in science education, the working memory space is easy to overload and the working memory demand of much learning strongly influences success. This is related to (a) the nature of science itself and to (b) the method by which science is taught in schools. The method by which students learn are in conflict with either (a) or (b) (Johnstone, 1984).

There may be several reasons why science is difficult:

- Scientific concepts are totally different from most other concepts in the everyday world (Herron *et al.*, 1977). When the teacher teaches the concept of element, he or she can show some piles of powder, some black (C), brown (Si) and yellow (S) and says 'these are all elements, each one consisting of atoms of the same kind'. However, there is nothing that appeals to the senses that helps to set out the concept of element. Moreover, the statement about atoms is not available to the senses either and students in general have no anchoring idea in long term memory.

- The use of language causes the working memory to overload. Unfamiliar vocabulary, familiar vocabulary changing its meaning as it moves into science, use of pompous language where plain language would do, use of unfamiliar constructions, and the unconscious use of double or triple negatives all make learning difficult (Cassels and Johnstone, 1982).

- In the laboratory class, there are often too many things to be manipulated cognitively at the same time. These are names of apparatus and materials to be recognized and associated, skills to be recalled, theories to be recalled, new skills, new written instructions and new verbal instructions. In this situation, students often cannot distinguish what is important from what is peripheral (the 'signal' from the 'noise')

- According to Johnstone (1993), science subjects can be seen as three levels of corners of a triangle (see figure 3.2); the macro level of the tangible, edible, visible, the sub-micro level of the molecular, atomic and kinetic, and the representational level of symbols, equations and mathematics. The teacher, as an expert in his or her topic, can easily move from one corner to another or operate anywhere within the triangle but it is not the case for student.

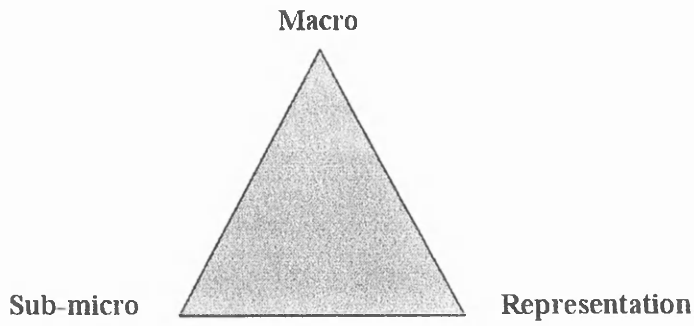



**Figure 3.2 The basic component of science**

*(From Johnstone, 1993)*

Johnstone and El-banna (1989) found an important relationship between working memory capacity of learners and their performance. They examined the data provided by the Scottish Examination Board on questions about the mole. The sample size was 22,000 sixteen-year olds. They plotted the fraction of the student sample solving each question correctly against the demand of each question: they defined the demand as the sum of pieces of information provided in each question plus the additional pieces to be recalled plus the processing steps required. In other words, the demand of the question can be described as the number of pieces of information the student has to hold at the same time in order to reach an answer.

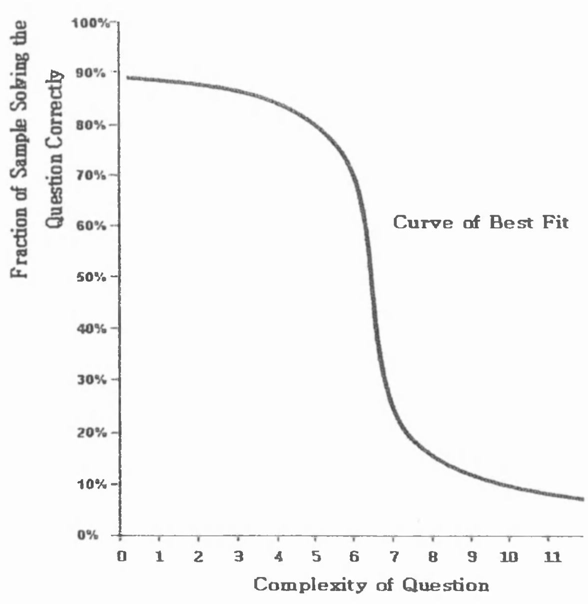



**Figure 3.3 Curve of best fit. Students have success with a series of questions of increasing complexity until a certain point, after which most students fail**

*(From Johnstone and Elbanna, 1989)*

Figure 3.3 above shows the curve of best fit indicating a high and a low plateau with a rapid drop between them. Therefore, it can be seen that if the complexity of the question exceeds the upper limit of the learner's working memory capacity, the performance suddenly drops.

Then, they divided students into three groups according to their working memory capacity (X) and plotted the average student performance against working memory demand (Z) of question for each group. Their three groups had a working memory capacity of five, six and seven. The results from schools and university students are similar and overall results can be seen figure 3.4.

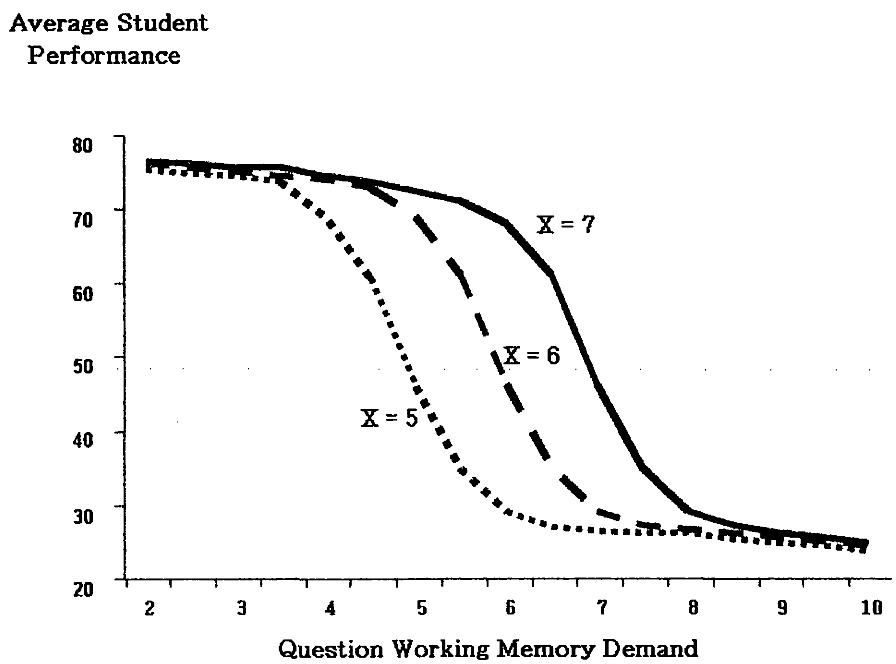



**Figure 3.4 The performance of students in examination questions of different demand, showing the division of the group into high, medium and low working memory capacities.**

The demand of a question is known as its Z-demand. Students with capacity X=5 do well with problems of demand Z=5 or less but do badly in problems where Z≥6, similarly X=6 students do well until Z≥7 and so on.

Of course, this does not mean that a student with low working memory capacity is incapable of learning successfully. There are many ways of avoiding working memory overload using chunking strategies. Nevertheless, it implies that teaching which does not take into account students' working memory capacity as a limiting factor rarely succeeds. Until now, the information processing model was described to understand how students learn and why learning science is not easy. It has never been used specifically to look at attitudes. Attitudes of teachers are very important in encouraging students towards greater success while the attitudes of pupils can be critical in enabling them to be successful (see Reid and Skryabina, 2002a). This is another big area to be considered to complete a perfect image of science education. The next chapter will focus on this.

# Chapter Four

# Attitudes to Science

This chapter offers a general review of attitude literature: the definitions of attitude, the process of attitude formation and change and especially attitude development in the context of science education. However, before discussing attitudes, it is important to ask why attitudes are important.

## 4.1 Why look at Attitudes in Science Education?

> *"As the details of scientific formulae fall away in the months and years after school, it seems likely that the crucial deposits of science and technology education are to do with attitudes, approaches and even values."*(King, 1989)

Many children enter school with great interest in science but the experience of school science makes them feel science is hard and inaccessible (see Hadden and Johnstone, 1982, 1983a, 1983b). The real problem is such impressions of school science persist much longer than any memories of Newton's Law, the formula for sodium chloride or the characteristics of living things (Jonathan *et al.*, 1998).

As a science educator, if the teacher fails to make students become practising scientists or study science in higher education, it can sometimes be seen to be disappointing. Nevertheless, it is not the mission of teachers to make as many practising scientists as possible. Human society needs various professional men and women such as politicians, businessmen, artists etc. as well as scientists. Indeed, the role of the teacher of a science subject is to make a contribution in developing educated pupils: pupils who can make sense of life and themselves; pupils who can appreciate the place and role of science in modern society; pupils who can relate their studies to culture, lifestyle and social importance.

The real danger is that the teacher produces a negative atmosphere in relation to science as a result of a knowledge-centered, difficult and boring science education. Gardner (1983) states that, "*We live in a golden age of science and technology, an age of space walks, satellite communication, and amazing advances in computing, in medicine, in chemistry. But if we examine the findings reported in the international research literature on* *students' interests in science, we cannot yet claim that the golden age of science education has arrived.*" Despite the intrinsic interest of scientific themes and their relevance for modern living, pupils' attitudes are often poor and may indeed be deteriorating.

In relation to the great advances in science and technology, there is another reason to emphasize attitudes. Enormous social and moral problems appear with scientific advances. There are many issues and people need help in judging and deciding about such scientific matters as genetic manipulation, environmental pollution and nuclear waste disposal. Therefore, a student's attitudes towards science may well be more important than his understanding of science, since his attitudes determine how he will use his knowledge (Reid, 1978).

On the other hand, looking at science education from the students' standpoint, the main aim of school science cannot be focused on training future practising scientists. Indeed, looking at a typical school intake in a Scottish secondary school shows that only around 20% of the intake will study for Higher Grade in any of the three main science subjects (Scottish Qualifications Authority, 2004). Of the intake, perhaps only 1 or 2% will become a practising bench scientist in any science discipline. It is possible to suggest that science courses must aim to achieve many things, including:

- An introduction to the empirical nature of enquiry as a valid method to obtain answers to questions about the physical and biological world;
- The development of a willingness to use this empirical method where appropriate;
- The preparation of the pupils and students to be informed citizens, able to make informed and rational judgments on matters relation to scientific developments.

In other words, students should be given opportunities to develop attitudes in relation to their studies in the science. This is the strong emphasis of the second and third aim, in particular.

For these reasons, attitude development is fairly important in science education. Furthermore, science educators should consider that students will develop attitude no matter what they do. It is, therefore vital for the teacher to provide students with opportunities to develop attitudes in a more structured and coherent way. Science subjects are sometimes taught in a way that is pretty cognitive and theoretical. There are high possibilities of misunderstanding about scientific matters and students' attitudes could be based on incorrect or only partial knowledge. Every science educator wants students to make intellectual sense of the world around them. It is the very nature of the work of science. Without careful attention to attitudes, the teacher might encourage the development of an attitude that is unhelpful and meaningless.

## 4.2 Definitions of Attitude

Numerous definitions have been offered:

> "*A mental and neural state of readiness to respond, organized through experience, exerting a directive or dynamic influence on behaviour.*" (Allport, 1935)
>
> "A *stable or fairly stable organization of cognitive and affective processes*" (Kats and Sarnoff, 1954)
>
> "*A concept with an evaluative dimension*" (Rhine, 1958)
>
> "*A state of readiness or predisposition to respond in a certain manner when confronted with certain stimuli...attitudes are reinforced by beliefs (the cognitive component), often attract strong feeling(the emotional component) which may lead to particular behavioural intents(the action tendency component)*" (Oppenheim, 1992)
>
> "*A psychological tendency that is expressed by evaluating a certain entity with some degree of favour or disfavour*" (Chaiken and Eagly, 1993)

These are all definitions of attitude by different researchers but there are many other definitions. Each definition has different meaning according to the context in which attitudes are considered and the point of view of a person defining attitude. Therefore, it may be impossible to present a precise definition with one sentence. However, it is possible to pick out several core factors which must be considered in constructing an attitude theory.

### 4.2.1 Attitude Objects

An attitude must have a target. In other words, an attitude has to be directed towards something or someone. Figure 4.1 shows four broad areas where attitude development is important in the field of science education.

- *Attitudes towards the subject being studied*

Considerable research has been performed to look at attitudes towards subjects like chemistry and physics (for a recent example of a large study looking at physics, see Reid and Skryabina, 2002a and 2002b). In this area, major concern among educators is how to encourage positive attitudes because, without interest in the subject being studied, it is very hard for the learner to be motivated to learn. What is to be taught and how it is taught might be the two major influences on students' attitudes.

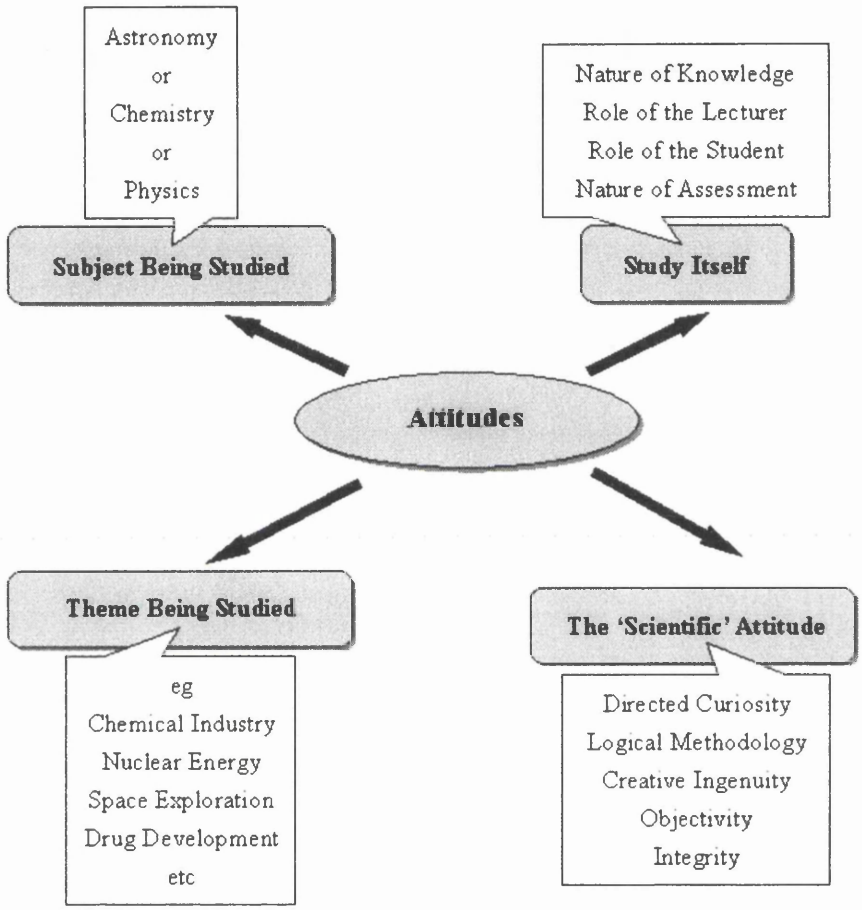



**Figure 4.1 Four broad areas of attitudes in science education**

***(From Reid, 2004)***

- *Attitudes towards the study itself (process of learning)*

There are skills for effective learning and it is necessary to look at attitudes towards learning these skills and using them. Students need to develop critical understanding about the nature of knowledge and how it is gained, about approaches to successful study, about the nature of learning as a life-long process and so forth. Pioneering work was carried out by Perry (1999) with university students and this has defined a language and an agenda.

- *Attitudes towards the process of science (the so-called scientific attitude)*

This is associated with what might be described as 'scientific method, or the range of attributes which encompass skills related to the undertaking of practical work and other more general dispositions towards the beliefs and procedures of science (Ramsden, 1998). The components of the scientific attitude mentioned in the literature are as follows (Byrne and Johnstone, 1987).

> *"Group 1 General attitudes towards ideas and information, i.e. 'curiosity', 'open-mindedness', etc.*
>
> *Group 2 Attitudes related to the evaluation of ideas and information. Such attitudes are often collectively labeled 'critical-mindedness' and include 'objectivity', 'caution in drawing conclusions', 'weighing evidence', etc.*
>
> *Group 3 Commitment to particular scientific beliefs, e.g. 'loyalty to truth', existence of cause and effect relationships', etc."*

- *Attitudes towards themes/topics/issues arising in the study of a science subject.*

Through the experience of learning science, students develop attitudes towards themes and topics which they study. As students learn more about chemical industry, they will develop attitudes towards aspects of the work of chemical industry. If students become to understand genetics, their attitude towards aspects of genetic engineering will be deepened. Studying topics which involve contemporary issues in science like pollution and nuclear industry will provide students with opportunity to develop attitudes towards these and related themes.

### 4.2.2 Attitudes as Evaluative

> "*Attitude is an evaluative state that intervenes between certain classes of stimuli and certain classes of response*" (Chaiken and Eagly, 1993)

People respond to stimuli that denote attitude objects with evaluation. Evaluative responses are those that express approval or disapproval, favour or disfavour, liking or disliking, approach or avoidance, attraction or aversion, or similar reactions. In the process of bringing evaluative response to attitude object, people develop their attitude and this process can be done on the cognitive, affective or behavioural basis or a mixture of them.

### 4.2.3 Cognitive, Affective and Behavioural Elements of Attitude

The responses that express evaluation and, therefore, reveal people's attitude can be divided into three classes: the cognitive, affective, and behaviour (Katz and Stotland, 1959; Rosenberg and Hovland, 1960). In addition, people's attitudes can be formed through cognitive, affective, or behavioural processes exclusively or through different combinations of them (Zanna and Rempe, 1988). Figure 4.2 shows this.

The cognitive category contains thoughts that people have about the attitude object. Cognitive process takes place when people obtain any information about an attitude object and form beliefs. Therefore, people who have positive attitudes about an attitude object tend to link it with positive attributes whereas people who have negative attitude tend to link it with negative attributes.

The affective category consists of feeling or emotions that people have in relation to the attitude object. Affective process can take place when people experience feelings, moods, and emotions like anger, hope, happiness and sadness. People who have favourable attitudes about an attitude object are likely to experience positive affective reactions in conjunction with it and are unlikely to experience negative affective reactions while people who have unfavourable attitude are likely to experience the opposite affective reactions.

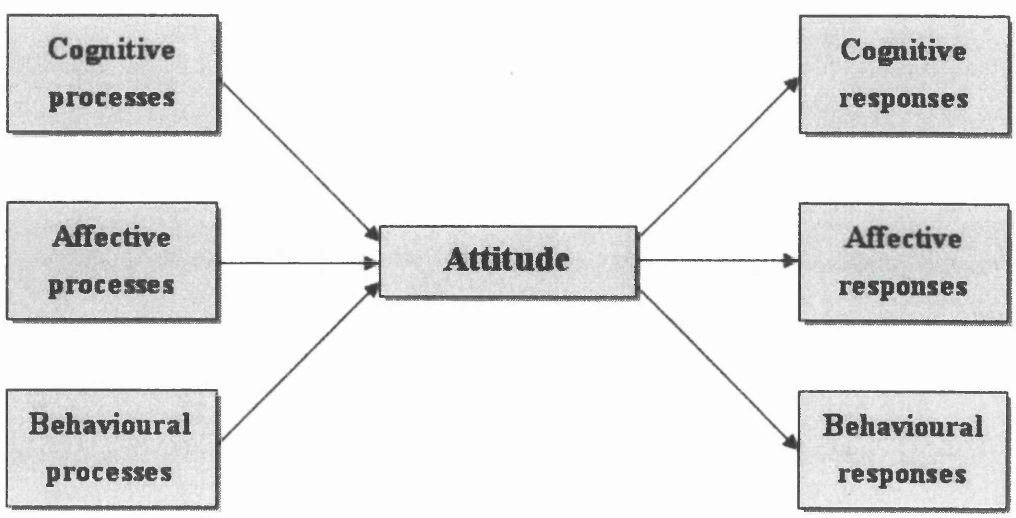



**Figure 4.2 Cognitive, affective, behavioural elements of attitude**

*(From Chaiken and Eagly, 1993)*

The behavioural category encompasses people's actions with respect to the attitude object. Behavioural forming of attitudes takes place when the evaluation about an attitude object builds on the basis of past behaviour. People tend to make evaluations that are consistent with their prior behaviour. People who evaluate an attitude object favourably tend to engage in behaviour that foster or support it or have intentions to act like that although they are not necessarily expressed in overt behaviour. People who evaluate an attitude object unfavourably tend to have the opposite tendency.

### 4.2.4 Latent Property of Attitude

An attitude is a latent construct that can be inferred by considering the observed stimuli and the observed evaluative responses (see Figure 4.3)

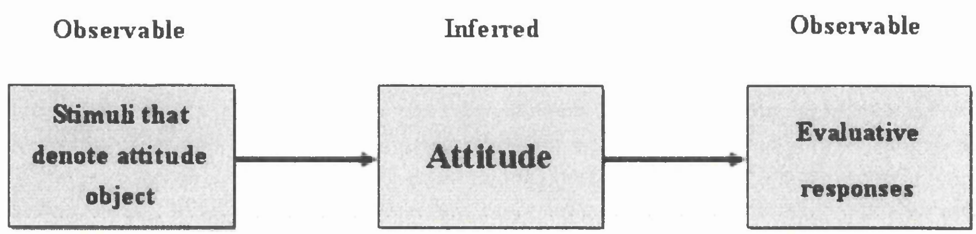



**Figure 4.3 Attitude as a latent construct**

***(From Chaiken and Eagly, 1993)***

Therefore, a person's attitude cannot be measured directly. It is possible to measure behaviour and then deduce what the attitude might be.

### 4.2.5 Functions of Attitude

According to Reid (2004, p. 33), in general, attitudes in life allow us to,

- Make sense of ourselves;
- Make sense of the world around us;
- Make sense of relationships.

Attitudes provide a frame of reference for the individual. People appreciate the world in terms of knowledge, feelings and behaviour, established beliefs, feelings and behaviour types with a logical and rational wholeness of meaning and determine acceptable patterns of social interaction.

## 4.3 Method of Attitude Investigation

Attitudes cannot be measured directly or in any absolute way. We can only infer people's attitudes from observed behaviour and look at changes in attitudes or differences in attitudes when comparing two or more groups. Many techniques have been developed for measuring attitudes.

- Questionnaires
- Observation of overt behaviour
- Physiological tests
- Partially structured stimuli (similar to projective tests)
- Performance of tasks (congenial material learned rapidly)
- Interviews

Among them, questionnaire and interviews are a practically useful way for educational research to explore various aspects of attitudes.

A well-constructed questionnaire can provide insights into how students think and the way they evaluate situations and experience. It might be thought that questionnaires are highly unreliable and of limited value. However, "the evidence shows that well constructed questionnaires can provide extremely accurate insights…" (Reid, 2004, p. 35)

The Likert method (1932), the Semantic Differential method (Osgood, Suci and Tannenbaum, 1957) and other written forms such as preference ranking and interest inventories have been widely used approaches in educational research in recent years. Reid (2004, p. 41) has offered a set of procedures which can help to develop a good questionnaire:

*(a) "Write down as precisely as possible what you are trying to find out;*
*(b) Decide what types of questions would be helpful;*
*(c) Be creative and write down as many ideas for questions as you can;*

*(d) Select what seem the most appropriate from your list - keep more than you need;*
*(e) Keep the English simple and straightforward, avoid double negatives, keep negatives to a reasonable number, look for ambiguities, watch for double questions;*
*(e) Find a critical friend to comment on your suggested questions;*
*(f) Pick the best, most appropriate and relevant questions, thinking of time available;*
*(g) Layout is everything!!*
*(h) Try your questionnaire out on a small sample of students (e.g. a tutorial group) - ask for comments, criticisms. Check time required.*
*(i) Make modifications and only then apply to larger group;*
*(j) Analyse each question on its own."*

Interviews are a very powerful tool to gain insights into student attitudes. A large amount of information can be produced by talking to students about their learning experience. Furthermore, interviews can be used to check the validity of the data obtained from questionnaires. Nevertheless, undertaking interviews has some disadvantages:

- Interviews take considerable time both for students and the researcher;
- It is difficult to translate evidence from interviews into a neat summary;
- There is the possibility that the interviewer may influence the way the interview is conducted and the way results are interpreted.

Therefore, for reliable and valid data, it is recommended to use a combination of questionnaire and interview.

### 4.4 Attitude Research in Science Education

There is wide range of attitude research in the field of science education. This review, therefore, concentrates upon the variables which are considered the possible ways attitude towards science can be formed and influenced. Those variables can be grouped into two broad categories:

- Internal or personal variables: personality, intelligence, achievement, sex and age.
- External or social variables: teacher and classroom environments, home background, curriculum, instructional variables.

These two groupings are by no means distinct and unrelated (Gardner, 1975):

- Some variables are difficult to classify unerringly (achievement is a matter of school policies and practices, and not just a matter of the pupil's ability).
- Some internal variables (eg. personality) may themselves be the result of external variables (eg. socialization practices)
- Some internal variables may interact with external variables in producing their effects; certain types of teacher behaviour may exert varying effects upon students of differing personalities.
- Internal perceptions of external variables may be more influential than the external variables *per se*; a child's attitudes may be influenced by his beliefs about his parents' attitudes and these beliefs may be unrelated to the attitudes which his parents actually hold.

### 4.4.1 The Research of Internal or Personal Variables

Much research has shown that boys are more positive towards science than girls (Bradley and Hutching, 1973; Keeves, 1973; Hilton and Berglund, 1974; Weinberg, 1995 etc.) Furthermore, the nature of boy's and girl's interests in science is inclined to differ. Physics topics are much more popular with boys than girls. Biology and social science topics are more popular with girls than boys (Comber and Keeves, 1973; Clarke, 1972; McGuffin, 1973; Graig and Ayres, 1988). On the other hand, Reid and Skryabina (2002b) found there are almost no differences in the interests of boys and girls in physics topics related to explanations of natural phenomena and understanding how physics can serve humankind. In general, boys are interested in physics topics related to technical objects and the way they function and physics as in a "scientific enterprise (physics for the sake of physics)". Girls' interests are physics in the context of its impact on society.

Piburn and Baker (1993) attempted to find causes for the general tendency that interest towards science decreases with age. According to their results, the origins of the decline in attitude towards science are in the nature of "classroom instruction and the relationships among people in classrooms." Many of the science activities at the primary stage are action-oriented and open-ended. Although children begin school liking science, they become increasingly uncomfortable with open-ended activities. They need instructions, assessment and feedback about their work. In addition, the abstraction and complexity of science lessons grow from year to year. This has a clear negative influence on attitudes toward science. They looked at the isolation of students as the major reason influencing decline of attitude toward science. As a student moves through the grades, the opportunities for student-student and student-teacher interaction, both academic and social, tend to decline and, therefore, negative attitudes increase. Overall, learners need security in their learning and they need to relate their studies to their experiences. Science syllabuses have frequently not taken these factors into account.

There are conflicting opinions concerning the relationship between attitude and achievement. Many studies showed the relationship between these two factors is weak (Gardner, 1983). According to Osborne, Driver and Simon's article (1998), this is supported by the fact that girls are marginally outperforming boys at GCSE in science in England but their participation post-16 in the physical sciences is disappointing. However, Eisenhardt (1977), when he surveyed a large number of students from grade six to eleven in West Virginia, USA, claimed results that showed that achievement in science, mathematics, social studies and English influenced attitude more often than attitude influenced achievement. On the other hand, Schibeci and Reilly (1983) suggested that attitudes influenced achievement more than achievement influenced attitudes. In the end, Schibeci (1984) suggested that there is a big possibility of two-way relationship between attitudes and achievement.

Which kind of students tend to have favourable attitudes towards science or are potential scientists? An extensive literature supports the view that attitudes are not isolated personal attributes. For example, Hutchings (1967) surveyed 50 boys and girls taking art and 50 boys and girls taking science with Cattell's 16 Personality Factor Questionnaire. Boys and science pupils were 'more realistic (no-nonsense), self-reliant, acting on practical, logical evidence'. Blake (1969) found, from his research with Canadian students, that the science-oriented students were more theoretically inclined, less extroverted, more interested in social relationships, less conformist (this is contrary to other studies), and more 'other-directed' (eg. more prone to be guided and influenced by other people). Soh's data (1973) from 170 able second-year boys in three grammar schools in England suggested that potential scientists were less-indulgent, pleasure-seeking, assertive and destructive, more concerned with school interests and family relationship, and more alert to external threats (e.g. disease, parental rejection, deviant behaviour)

Overall, it is difficult to summarize all findings in a few words, nevertheless, the general picture which emerges is that students who are favourably inclined towards science tend to be relatively serious and achievement-oriented, realistic and independent, but conventional and conformist (Gardner, 1975)

### 4.4.2 The Research on External or Social Variables

Germann (1988), Reid and Skryabina (2002a) and many other researchers found that teachers and their instructional method play a very important role in forming students' attitudes toward science. In relation to this, Perrott (1982) reviewed several research projects (Ryan, 1960; Flanders, 1970; Rosenshin and Furst, 1973) and summarized the characteristics of teachers who are able to foster gains in achievement and stimulate positive attitude to learning. According to her summary,

- Teacher's cognitive organization which is clear, business-like and task-oriented is important;
- Transmissive teaching had strong negative affects upon student's interest in science.
- Effective classroom teaching is using a variety of instructional material and procedures.
- Students benefit from active student involvement and experimentation and the use of visual aids by the teacher.
- Teacher dominated techniques (excessive teacher talk, copying of notes, rote-learning of textbook material) tend to inhibit interest.

Looking at this list, it would appear that such teacher characteristics are those which describe the effective teacher in any subject area and they do not offer a clear way forward which is specific to the sciences.

As children grow up, not only content but also the way scientific knowledge is to be used become significant for many students (Gardner, 1983). In particular, teenagers begin to be concerned about social issues. Several countries report on the benefits of teaching science in ways which permit the social and environmental consequences of science and technology to be considered (Gardner, 1983).

Finally, the most significant factors which make students give up studying science are its perceived difficulty (Cheng, Payne and Witherspoon, 1995). Many students state that they do not want to continue with science because it is too mathematical, too abstract and too difficult. Consequently, science, especially physical science, is only taken by students who do well and this reinforces the notion that science is difficult and is, therefore, only for the intelligent.

It is interesting to note that, in Scotland, the sciences are very popular at school level (Scottish Qualifications Authority, 2004), being the top three subjects at the Higher Grade (entry to Higher Education) of all elective subjects. There is little sense that sciences are restricted to the intellectually elite. The reason for this is complex but relate to the ways syllabuses have been constructed as well as social expectations (Skryabina, 2000).

## 4.5 Attitude Development in Science Education

It is the desire of all science educators to make their students interested in science subjects. However, more than interest is needed. What is really wanted is that students plan their future on the basis of true comprehension about scientific knowledge, scientific process and the role of science in a scientific and technological society. In order to do this, it is necessary for students to be concerned about the matter of science whether they become a specialist in science or not. This is real meaning of "attitude development in science." This explains why Reid (e.g. Johnstone and Reid, 1981) stresses attitude 'development' rather than attitude 'change', a term which social psychologists often use. The learning situation should allow pupils to develop attitudes on a sound cognitive basis. Nevertheless, although the models from research of social psychology tend to use the word 'change' (with its possible overtones of manipulation), these models are very helpful to understand attitude *development* in science.

There are many models for attitude formation and change (e.g. Functional Theories, Consistency Theories, Social Judgment Theory and Information Processing Theories etc.) which have been arisen in the field of social psychology since 1950. Among them, theories that have been particularly relevant for science education are Information Processing Theories, Cognitive Response Theories and Consistency Theories. However, only Information Processing Theories and Cognitive Response Theory will be described here since those two theories are related to this research.

### 4.5.1 Information Processing Models

Confusingly, this kind of model is not related to the cognitive information processing model discussed in chapter 2. Basically, these models are a kind of process theory which was developed as a persuasion model. The process theory provides accounts of how beliefs and attitudes form and change when people process relatively complex messages. Therefore, this model attempts to explain the mechanism that influence people's tendencies to accept information to which they are exposed (Chaiken and Eagly, 1993).

According to Hovland, Janis and Kelley's early research (1953), the impact of persuasive communications could be understood in terms of three information-processing phases:

(a) Attention to the message;
(b) Comprehension of its content;
(c) Acceptance of its conclusions.

In other words, attitude change is brought about by means of a new message and this incoming information should be comprehended by the recipient. Then, it is evaluated and integrated. Of course, related cognition and attitudes held in long term memory are retrieved and influenced in this process.

There are two main routes for information processing: the central and the peripheral routes. Recipients who follow the central route work hard at evaluating the message logically. Attitude change through the central route is due to careful reasoning and argument quality is important. On the other hand, the recipient who follows the peripheral route depends on peripheral cues to evaluate the message. This route does not involve any active thinking and attitude can be changed just under the influence of emotions or impressions such as source attractiveness and prestige. In looking at this approach overall, the actual attitude change may depend on many variables:

- Nature of message source
- How message is presented
- Extent that subjects attends to the message
- Extent to which the subject understands the message
- How the subject evaluates the message
- How the subject integrates the message with previous knowledge.

Therefore, in educational situations, the teacher should try to make their teaching materials fulfill the following necessary conditions in other to develop students' attitude related to science:

- The message source must have high credibility.
- The message must be of high quality
- The perceived relevance must be high to encourage good comprehension
- Time and opportunity must be allowed for message-related thinking
- Message related thinking to give attitude change only occurs when subject possesses sufficient motivation and ability to process message.

### 4.5.2 Cognitive Response Models

Cognitive Response Models share basic processes of attitude change with Information Processing Models but they emphasise the mediation role of the idiosyncratic thoughts or "cognitive responses" that recipients generate, and thus rehearse and learn, as they receive and reflect upon persuasive communications (Greenwald, 1968; Petty, Ostrom and Brock, 1981).

According to Cognitive Response Models, people do not merely repeat message content. They actively relate new information to their existing feeling and beliefs. Then this internal communication produces cognitive responses reflecting recipient-generated thoughts. Messages that evoke predominantly favourable recipient-generated thoughts should be persuasive, whereas those that evoke most unfavourable thoughts should be unpersuasive.

Much work in relation to Cognitive Response Models arises from Yale University (Hovland *et al*, 1953; Janis and King, 1954; King and Janis, 1956) and key messages for science education are as follows:

- It is important for the subject to relate messages actively to existing feelings and beliefs;
- Active participation in the attitude change input is important;
- Role play is a very effective approach;
- Scope for improvisation in role play is an important feature;
- Subjects must be free to participate (not forced);
- Commitment to the counter-attitudinal argument is important;
- Personal responsibility in outworked behaviour is important.

In the process of learning, information is processed cognitively by the learner and the information processing model of Johnstone (1993) offers valuable insights into the processes involved. However, as information is processed, held attitudes may affect information selection and the way it is handled. Equally, new information, as it is integrated into the long term memory may bring about attitude development. Chapters 2 and 3 have sought to offer a brief overview of the cognitive processes and the attitudinal processes. These two aspects occur simultaneously in real educational situation and interact with each other continuously. The next chapter will be about interaction of these two factors.

# Chapter Five

# The Interaction of the Cognitive and Affective in Science Education

Many studies have explored the difficulties of learning in the sciences and made many practical suggestions (eg. Johnstone and Wham, 1982; Johnstone, *et al*, 1993; Johnstone, 1997). This study has paid more attention to students' attitudes towards science. In this chapter, an attempt is made to bring these two areas together, but it is recognized that this is an exploratory study.

Attitudes influence the learning process continuously. Students' attitudes may control whether they display their ability completely or almost not at all in learning activities. In addition, attitudes can be affected by learning experiences the learner has although attitudes are resistant to change. Therefore, the way to make the most of this interaction should be developed in order to achieve both cognitive and affective objectives in science education.

## 5.1 The Impact of Attitudes on Learning

Attitudes may influence the perception filter because people perceive only what they wish to perceive. Without an interest in the subject being studied, it is hard for the learner to be motivated to learn. In particular, if a student has a negative attitude toward learning itself or the topic being presented, he/she may not attend to the learning material actively and, therefore, new learning can be disturbed from the beginning. If the learner has low confidence about subject being learned, the learner may not be able to function to his/her capacity fully. Furthermore, he/she tends to hesitate to take cognitive risks which are important to active thinking and investigation.

According to the research of Laukenmann *et al.* (2003) about the influence of emotional factors on learning in physics, subject-specific self-concept shows a very high correlation with final test performance and interest is more important in the situation with no performance pressure than in learning under performance pressure.

On the other hand, favourable attitudes make learners attend to new information positively. Those learners who have favourable attitudes towards the subject being studied are willing to spend their time in studying that subject and make every effort to comprehend the message. Furthermore, favourable attitudes:

- *"Help the individual learner to reinforce previously learned skills.*
- *Lead to the achievement of some important skills, such as communication, co-operation, competition etc.*
- *Lead to the interaction among the learners and also between each individual learner and his teacher.*
- *Help the individual learner to make his own decisions.*
- *Help the individual learner to reduce the inconsistency caused by introducing new information to him.*
- *Help the individual learner to organize knowledge in a way which is simpler to him."*

(Nasr, 1976)

## 5.2 The Impact of Learning Experience on Attitude

Gardner (1985) suggests that there are four key questions which need to be answered in order to yield information on interest in science.

> *To what extent are students interested in using science to meet personal needs? To what extent do they want to learn about [scientific] issues which affect society at large? How strongly are they motivated by the possibility of pursuing academic work in science? How willing are they to consider the possibility of a scientific or technological career?*

It is clear from the above discussion that cognitive content is an essential component to raise students' interest in science. If students have no previous knowledge and skill about scientific aspects of their everyday life, scientific issues of society, and industrial and economical application of scientific outcomes, how can their interest in science grow? This is the reason why many students state that they do not want to continue with science because it is perceived as too mathematical, too abstract and too difficult. In addition, topics like pollution, world poverty, industry and society, nuclear developments, research, smoking, etc. have a dominant cognitive base. In order to develop attitude about these topics, much factual evidence should be provided. An attitude formed without taking the cognitive base into account can be described as a prejudice. It is also important to know whether students can comprehend well about the nature of science and the role of science in society or not. If students know more about science and how it is used, their attitude *may* improve although this cannot be guaranteed. Therefore, cognitive comprehension is an indispensable factor of attitude development.

Repeated failure in learning may produce:

- Poor information in long term memory about an attitude object;
- Poor chunking which leads to short term memory's overload and consequently miscomprehension or no comprehension about attitude object;
- Negative attitude storage in long term memory which may hinder further learning;
- Low confidence;
- Memorization with little understanding as a way of learning.

In conclusion, unsuccessful learning experiences can cause students to lose learning intention. This may bring about negative influences on attitudes or loss of ability to study because there is little or no prior knowledge in long term memory. Such knowledge is important in making sense of new learning. Inevitably this produces another unsuccessful learning the next time. The result of this vicious cycle may be one of the reasons for general public antipathy against science about which many science educator and others in science community are anxious.

## 5.3 Cognitive Strategies for Developing Desirable and Well-informed Attitudes

There are ten factors that may influence attitudes (Khan and Weiss, 1973). Figure 5.1 shows these.

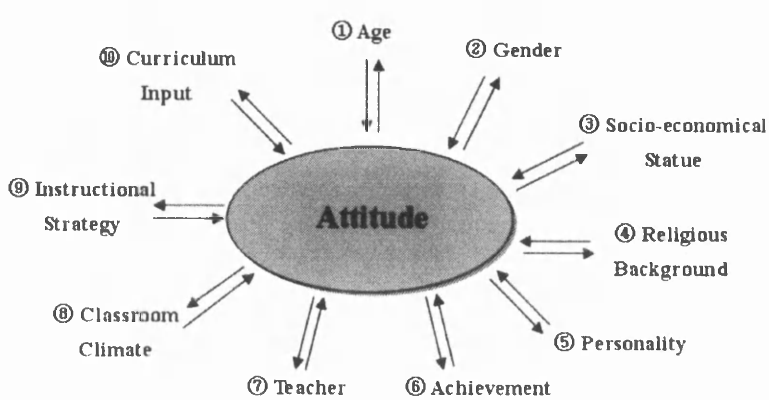



**Figure 5.1 Attitude and its variables**

Among these, only 8, 9, and 10 are within the teacher's control although 6 can be influenced. In particular, 9 and 10 have a strong cognitive nature. Therefore, those two factors are mainly considered here.

How are students' attitudes developed? The processes can be summarized in the following diagram (Figure 5.2) based on the discussions of Chapter 4. The important aspects of input stage are the characteristics of content provided: namely, what is to be presented and how it is presented. No content can influence a student's attitude unless it motivates students to be willing to receive. Therefore, student's perceived relevance of the subject and self-confidence about ability to understand it must be gained.

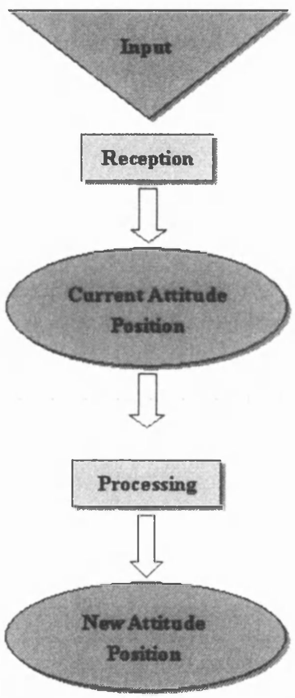



Figure 5.2 The Processes of Attitude Development

In the stage of processing, the new input has to be comprehended and assessed. Attitude is not merely developed by acquisition of relevant information. It needs to be internalized or "made one's own." Its implications for making sense of the world and for possible patterns of behaviour need to be considered. The attitude may have to be connected meaningfully to other related attitudes to make a coherent whole. For this reason, student should participate actively in the learning process.

Of course, all these processes are considered in relation to students' current attitude position. The aspects to be considered are as follows.

- *"Cognitive and affective baseline;*
- *Established behavioural baseline;*
- *Held attitude position and strength;*
- *The nature of the matrix of cognitions and affects that are embedded in the attitude;*
- *Extent of internalization;*
- *Extent of ego-involvement."* (Reid, undated)

Now it is possible to establish several guiding principles for desirable and well-informed attitudes in science education.

(1) The science curriculum must meet the learner's needs in the sense that it is perceived by the learner as relevant in the context of lifestyle and society;
(2) The science curriculum must meet the learner's needs in the sense that it enables to the learner to make sense of his world;
(3) The material presented to the learner must be accessible: it must be capable of being understood rather than memorized; it must not make unrealistic demands on working memory;
(4) The teaching programme must offer the learner appropriate opportunities to become involved actively with the material being taught: to interact actively and make it one's own.

The study conducted by Skryabina (Reid and Skryabina, 2002a) found that the Scottish Standard Grade course was constructed as an applications-led course. In this, the topics to be covered were determined by the seven themes of the syllabus: Telecommunication, Using Electricity, Health Physics, Electronics, Transport, Energy Matters, Space Physics (Scottish Qualifications Authority, 2004). More details can be seen in Appendix D.

She followed the way attitudes towards physics developed during the course and observed the very marked improvement in attitudes throughout the course. At the end of the course, attitudes were so positive towards physics that about 90% of all pupils expressed the wish to continue with studies in physics, a remarkable observation. Aitkenhead (2003) also found very positive attitudes although it never reached the 90% mark. Other observations support the idea that, when pupils perceived their studies to be related to themselves and their lifestyle, their attitudes develop very positively towards the subject. This work has been reviewed by Reid (1999, 2000).

The second principle is built on the idea that humans are seeking to make sense of the world around, themselves and relationships. Science has a particular part in the first of these. When science is presented in such a way that it remains abstract and lacking meaning, attitudes will not develop positively in that this innate human need is not being met.

The third principle is now well established by the numerous research studies showing how meaningful learning more or less ceases when working memory is overloaded (see Johnstone, 1997, for an overview).

The fourth principle derives from the enormous amount of research on attitude development carried out in the field of social psychology. It was first pinpointed as a key principle in an educational setting by Reid (1978). He tested the principle out with large samples of school pupils and found that it was a critical principle (see Johnstone and Reid, 1981).

According to these principles, every science educator should consider the following details when they plan their teaching program:

- Development of an application-led course related to real life situation such as health physics, transport and communications;
- Presentation of career prospects related to science. Particularly, early subject-related career education for girls is necessary to help them to overcome existing gender-related stereotypes about science;
- Development of teaching material related to social context of science. Historical, domestic, industrial, economic and socio-moral aspects of science should be reflected in a science curriculum (Reid, 1978);
- Presentation of contemporary role models and actual working practices of scientists;
- Careful consideration of students' stage of growth, their age and working memory capacities;
- Adherence to appropriate difficulty level which arouse students' intention to challenge intellectually;
- Development of proper communication skills suitable for students and using various audio-visual materials.
- Setting up teaching material of high credibility and high quality;
- Providing enough time and opportunity for message-related thinking;
- Providing variety of experience. It may encourage students to participate actively and give them opportunities to internalise. Role play, problem solving and discussion are examples;
- Involving students in the teaching strategy as much as possible. It could be achieved by talking with students, individually and in groups, and making every effort to implement their suggestions.

All the things discussed in this chapter would not be new for most educators at all. However, if we think about how many of these are realized in current science education, it may make us think of their importance once again.

# Chapter Six

# Methodology of the Research

This chapter describes the way this study was carried out. The extent of research, the research questions, and the methods of data collecting and analyses are discussed.

## 6.1 The Extent of Research

This research aims to explore the relationship between the cognitive and attitudinal fields in the learning of science. This offers a huge area for exploration. Therefore, this research is designed to focus on only a few aspects

Johnstone's information processing model (1993) is used to account for cognitive aspects of science education. Learning processes are understood in terms of a student's own knowledge construction through the operation of perception filters, processing in working memory space and storing in long term memory. In particular, the overload of students' working memory space is considered as the main factor causing learning difficulty and, in consequence, learning failure.

In the realm of attitudes, there are two different ways in which the term *attitude* is used in relation to science. Gardner (1975) made the distinction between attitude to science and scientific attitudes. Attitude to science refers to the views and images young people develop about science as a result of influences and experiences in a variety of different situations. On the other hand, scientific attitudes are something like 'scientific method' and 'style of thinking'. This research is concerned with attitude to science rather than scientific attitudes. Students' attitudes towards science subjects, scientists and processes of learning are mainly explored. However, attitudes towards social aspects of science are not considered in that this would have involved too wide a study demanding too much time from the pupils concerned.

Students obtain their image of science through various channels such as school science classes, TV programmes, literature, parents and peer group etc. In other words, students' images of science are influenced by their experience in school and outside school. The focus of this research is on school science as experienced in school rather than outside school science. Besides, students' beliefs about biology may differ from beliefs about physics or chemistry. However, in this research, the term science does not mean any separate discipline. The research sample is middle school students in South Korea and, at this stage, there is no division within science. In consequence, they have no concept about the terms physics, biology and chemistry etc.

## 6.2 Students' Sample Involved in the Research

For this research, one middle school located in Seoul, the capital city in South Korea was selected. It has 12 classes for each level and the average number of students per class is 35. There are slightly more boys than girls. The research was conducted with level 1 (age 12) and level 3 (age 14) students. 364 responses from level 1 and 350 responses from level 3 were obtained. The table 6.1 shows the sample of students participating in the research according to their level and sex.

| | Boys | Girls | Total |
|---|---|---|---|
| **Level 1 (age 12)** | 191 | 173 | 364 |
| **Level 3 (age 14)** | 173 | 177 | 350 |

**Table 6.1 The sample of students participating in the research**

The students have diverse home backgrounds but generally are from the middle classes and more than half of them take out-of-school studies as explained in chapter 2.

## 6.3 Research Questions

Four research questions were brought forward:

- What is the general pattern of Korean middle school students' attitudes towards science?
- How do students' attitudes towards science change during their middle school life?
- Are there significant correlations between students' attitudes and their working memory space?
- Is there any relation between students' ideas about various aspects of learning science and working memory space?

## 6.4 Methods of Research

In order to try to find relationships between cognitive and affective factors of science learning, individual student's working memory space was measured and a questionnaire designed to gather information about students' attitudes was prepared and given to both level 1 and level 3 students.

### 6.4.1 Measurement of Working Memory Capacity

The Figural Intersection Test (F.I.T), designed by Pascual-Leone (1970), was used to measure a student's working memory space. To determine the quantity of information which can be held and processed in student's working memory at one time, F.I.T gives pupil two sets of simple geometric shapes (see figure 6.1). The presentation set (on the right) contains several simple shapes separated from each other. The test set (on the left) contains the same shapes but overlapping, so that there exists a common area which is inside all of the shapes. Then student has to look for and shade in the common area of overlap. In some items, there are some extra shapes in the presentation set which are not present in the test set and do not form a common area of intersection with all of the other shapes. There are altogether 36 items on the test. The full test is shown in Appendix A.

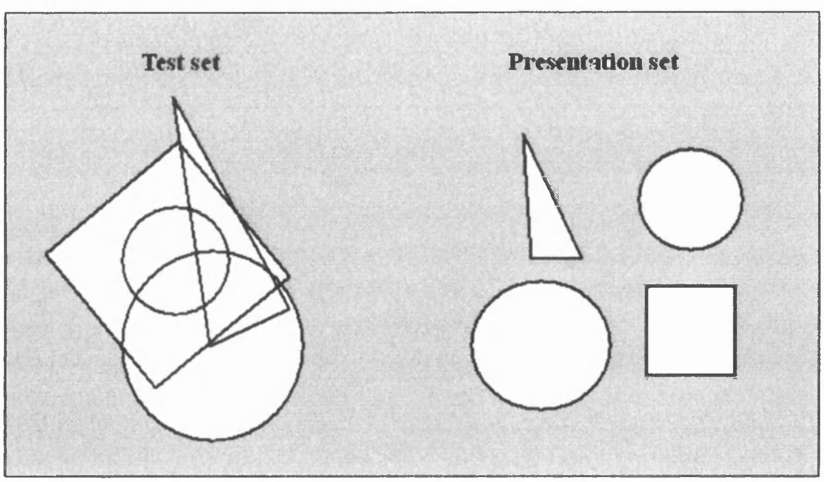



**Figure 6.1 Figural Intersection Test**

The number of shapes in one item varies from 2 to 9. If a student identified the common area correctly up to 5 overlapping shapes, his or her working memory space is scored 5. A student identifying correctly up to 6 is given score 6. In any other case, the scoring system is same. Every item has to be completed in about 15 seconds.

### 6.4.2 Questionnaire

To probe students' attitudes towards science, two sets of questionnaires for level 1 and level 3 were designed but, in both sets, all questions except one (question number 12) are same. Appendix B shows the questionnaires in full.

The Semantic Differential method and the Likert method were both employed for the questions aimed at obtaining information of an evaluative character. These methods are the most commonly used techniques in attitude survey and many education researches have employed them. A six point Semantic Differential scale was used to investigate students' view about studies in science and the scientist. Several sets of two bipolar meanings in each are presented for pupils to rank their evaluation. For example, the statements like 'I enjoy my studies'/ 'I do not enjoy my studies', 'I find science difficult'/ 'I find science easy', are presented about studies in science. For the questions about pupils' self-perception and their views about helpfulness of various aspects of learning science, the Likert method was used with four (all the time, quite a lot, a little, not at all) and five (strongly agree, agree, neutral, disagree, strongly disagree) scales.

The questionnaire also included questions aimed to gain general information about various aspects of learning, namely, the reasons of studying science, factors causing them to lose interest in science and the way of learning and so on. For these questions, other types of question were employed:

- Yes or No questions
- Multiple tick questions, where students could choose as many options as they wish
- Preference ranking questions, where students choose three things they feel most appropriate.

The Figural Intersection Test and attitude questionnaire were administrated in November, 2004, the middle of the second term. Being different from the United Kingdom education systems, the South Korean school has two terms. The first term starts in March and second in September. 364 responses from level 1 and 350 responses from level 3 were obtained.

### 6.4.3 Analyses of Data

In the present study, two kinds of analysis, comparison and correlation, were performed with data from the Figural Intersection Test and questionnaire applied to level 1 and level 3 students. For the comparison of attitudes between level 1 and level 3 students, the distributions of frequencies of responses were analyzed for each particular statement in a question. The Chi-square ($\chi^2$) test was applied to judge the statistically significant differences in responses of the two groups. The levels of significance used were 0.05, 0.01 and 0.001.

In order to see whether there is difference of opinions related to various aspects of learning science between level 1 and 3 students, and between high and middle and low working memory capacity groups, students responses were presented as percentages of the total number of each groups. Then it is compared by just looking at the distribution of percentages without doing more statistics on these.

Finally, correlation coefficients were calculated to see if students' working memory capacity is linked with attitudes. Data from attitudes questionnaires are far from normal distributions and expressed in rank of grade along a continuum. In addition, in this work, the Semantic Differential and the Likert method were used to probe students' attitudes towards science and scientists so that there are just four to six categories in students' responses. Examples are given below in figure 6.2.

**Figure 6.2 The examples of Semantic Differential and the Likert method used in the questionnaire**

I enjoy my studies ☐ ☐ ☐ ☐ ☐ ☐ I do not enjoy my studies

Scientist is responsible ☐ ☐ ☐ ☐ ☐ ☐ Scientist is irresponsible

| | *strongly agree* | *agree* | *neutral* | *disagree* | *strongly disagree* |
|---|---|---|---|---|---|
| I am coping with science task very well | ☐ | ☐ | ☐ | ☐ | ☐ |
| Science is an important subject for my life | ☐ | ☐ | ☐ | ☐ | ☐ |

Therefore, Kendall's tau-b method of correlation was adopted since it is appropriate when data are ordinal but there are few categories. The data obtained in this study are such data.

# Chapter Seven

## South Korean Middle School Students' Attitudes towards Science

In this chapter, as a result of questionnaire analyses, students' attitudes towards studies in science, scientists and students' self-perception in studying science are described first. Then students' general views about various aspects of learning science are discussed. Comparison is made between level 1 (age 13) and level 3 (age 15) by using a cross-age analysis (measurement at only one time with students of different age) to investigate how their attitudes change. The chi-square statistic is employed to test for significant differences between level 1 and level 3.

### 7.1 Students' Attitudes toward Studies in Science and Scientists

A six-point scale semantic differential method was used to judge the students' attitudes toward studies in science and the scientist. The question can be seen in Appendix B. Table 7.1 shows the distribution of level 1 and level 3 students' responses to different aspects of studies in science and the chi-square values to compare the difference of attitude between level 1 and level 3. In this table and in the remaining tables of this chapter, the white boxes are for level 1 and shadowed boxes are for level 3. The data are shown as percentages for clarity, rounded to the nearest whole number. However, the real frequency numbers were used for chi-square statistic calculations. Some students failed to answer in some items so adding up all the figures in such items does not always come to a hundred. In all tables, level 1 is shown on the top line with level 3 below.

The data from table 7.1 show that both level 1 and level 3 students thought science is useful and science topics are relevant to them. As they grow older, the belief that science topics are relevant to them is weakened but many students still think positively about the relevance of science topics. The belief that science is useful is fairly strong and does not change during their middle school life. This might be fundamental attitude (Reid, 1978) which they developed before they start formal education in school through TV programmes, literature and parents and so on.

**Table 7.1 students' attitudes toward studies in science**

| | Level | | | | | | | | $\chi 2$ | Probability | df |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I enjoy my studies | Level 1 | 14 | 16 | 26 | 20 | 12 | 11 | I do not enjoy my studies | 64.1 | <0.001 | 5 |
| | Level 3 | 7 | 15 | 18 | 20 | 21 | 19 | | | | |
| I find science difficult | Level 1 | 17 | 22 | 24 | 18 | 13 | 7 | I find science easy | 22.5 | <0.001 | 4 |
| | Level 3 | 22 | 27 | 24 | 17 | 8 | 3 | | | | |
| Science is useful | Level 1 | 32 | 24 | 28 | 13 | 1 | 2 | Science is not useful | 6.8 | n.s | 3 |
| | Level 3 | 26 | 27 | 28 | 10 | 5 | 3 | | | | |
| Science is boring | Level 1 | 12 | 14 | 18 | 29 | 14 | 14 | Science is interesting | 13.4 | <0.05 | 5 |
| | Level 3 | 15 | 15 | 20 | 27 | 14 | 9 | | | | |
| Science topics are irrelevant to me | Level 1 | 4 | 8 | 17 | 27 | 19 | 25 | Science topics are relevant to me | 55 | <0.001 | 4 |
| | Level 3 | 10 | 11 | 20 | 28 | 20 | 11 | | | | |
| There is too much work | Level 1 | 12 | 10 | 25 | 24 | 17 | 12 | There is not enough work | 19.7 | <0.01 | 5 |
| | Level 3 | 13 | 16 | 24 | 25 | 12 | 8 | | | | |
| Laboratory work is good fun | Level 1 | 50 | 23 | 13 | 5 | 3 | 6 | Laboratory work is not good fun | 62.2 | <0.001 | 4 |
| | Level 3 | 31 | 25 | 18 | 9 | 9 | 7 | | | | |
| I learn nothing from laboratory work | Level 1 | 3 | 5 | 11 | 22 | 28 | 31 | I learn a lot from laboratory work | 95.4 | <0.001 | 4 |
| | Level 3 | 9 | 9 | 17 | 27 | 25 | 14 | | | | |
| My textbooks are helpful | Level 1 | 19 | 19 | 25 | 16 | 12 | 9 | My text books are not helpful | 39.9 | <0.001 | 5 |
| | Level 3 | 9 | 13 | 27 | 22 | 14 | 14 | | | | |

Level 1 (N = 364) Level 3 (N = 350)

Note in this table 7.1 and in the remaining tables of this chapter.

- "df" is "degrees of freedom"
- "ns" means "not significant"

The opinions about laboratory work were so positive that the majority thought laboratory work was good fun and they learn a lot from the laboratory although, as they grow older, their attitudes to laboratory work tend to become more negative. This result is consistent with findings from Piburn and Baker (1993). According to them, students enjoy when they are allowed to actually manipulate apparatus and have first-hand experience. Moreover, experiments provide the opportunity to work with others and this is highly motivating to students because, by the junior high school, friends are important.

However, in spite of all these positive attitudes, students feel science is difficult and this tendency is intensified through the experience of their middle school science. Besides, it is found that a large number of level 3 students do not enjoy their studies comparing to level 1 students. This suggests that the difficulty in studying science may lead to students' alienation from science.

Table 7.2 shows the distribution of level 1 and level 3 students' responses to question about scientists and chi-square values. In general, students have positive opinions about scientists. However, scientists are not popular among students. In other words, many students believe a scientist is responsible, clever, valuable to society and involved with people but their emotion toward scientist might be described as not very good. It is impossible to judge the reason for this phenomenon from this research. However, it might have implications for science education. For example, it might be a reflection of the discrepancy between what students learn about science from various sources such as TV programmes, literature and what students experience actually in relation to studying science. Students have heard modern society was made by scientific progress and, without science and technology, it cannot maintain its prosperity. Nevertheless, they think science is too difficult and theoretical. They might not know how to relate science which they learn from school to their everyday life. Therefore, they might think science is valuable to society but it is just for people who are very clever and not for them. It might be due to lack of subject-related career education. It should be questioned how much students know about scientists as a job, their everyday work and their matters of concern and so on.

**Table 7.2 students' attitudes toward scientists**

| | | | | | | | | $\chi 2$ | Probability | df |
|---|---|---|---|---|---|---|---|---|---|---|
| responsible | 29 | 20 | 32 | 11 | 3 | 3 | irresponsible | 62.2 | <0.001 | 4 |
| | **22** | **20** | **27** | **16** | **10** | **5** | | | | |
| clever | 54 | 22 | 16 | 4 | 1 | 3 | dull | 18.4 | <0.001 | 3 |
| | **46** | **32** | **14** | **5** | **1** | **2** | | | | |
| rich | 11 | 7 | 29 | 25 | 12 | 16 | poor | 22.5 | <0.01 | 5 |
| | **9** | **11** | **32** | **23** | **14** | **10** | | | | |
| valuable to society | 48 | 29 | 13 | 7 | 1 | 2 | worthless to society | 3.5 | n.s. | 3 |
| | **46** | **30** | **15** | **4** | **3** | **1** | | | | |
| popular | 7 | 7 | 23 | 34 | 13 | 16 | not popular | 21.0 | <0.001 | 4 |
| | **4** | **7** | **23** | **31** | **21** | **15** | | | | |
| involved with people | 26 | 24 | 22 | 14 | 6 | 9 | detached from people | 46.3 | <0.001 | 5 |
| | **17** | **24** | **20** | **15** | **14** | **9** | | | | |
| a hard worker | 41 | 27 | 21 | 7 | 2 | 4 | not a hard worker | 15.0 | <0.01 | 3 |
| | **32** | **34** | **23** | **8** | **2** | **1** | | | | |
| doing a dangerous job | 7 | 4 | 11 | 23 | 25 | 31 | doing a safe job | 22.4 | <0.001 | 4 |
| | **3** | **4** | **10** | **26** | **32** | **24** | | | | |

Level 1 (N = 364) (unshaded rows); Level 3 (N = 350) (shaded, bold rows)

The responses of level 3 students tend to be more neutral than those of level 1 students. It appeared that students take more prudent attitudes toward the scientist as they grow older.

## 7.2 Students' Self-perception in Studying Science

For the questions about students' self-perception and their views about helpfulness of various factors in learning science, the Likert method was used with four (all the time, quite a lot, a little, not at all) and five (strongly agree, agree, neutral, disagree, strongly disagree) scales. The questions are shown in Appendix B. The results about students' self-perception are collected in Table 7.3.

**Table 7.3 Students' self-perception about studying science**

| | *Strongly agree* | *Agree* | *Neutral* | *Disagree* | *Strongly disagree* | $\chi^2$ | **Probability** | **df** |
|---|---|---|---|---|---|---|---|---|
| I am coping with my science work very well | 6 | 20 | 53 | 15 | 6 | 23.4 | <0.001 | 3 |
| | **4** | **17** | **47** | **22** | **9** | | | |
| Science is an important subject for my life | 11 | 23 | 41 | 18 | 7 | 76.6 | <0.001 | 4 |
| | **6** | **18** | **32** | **34** | **11** | | | |
| I am getting better at science | 9 | 32 | 35 | 17 | 6 | 45.6 | <0.001 | 4 |
| | **6** | **21** | **37** | **25** | **10** | | | |
| My understanding about the natural world is progressing by virtue of studying science | 12 | 26 | 39 | 17 | 6 | 17.7 | <0.01 | 4 |
| | **7** | **28** | **33** | **23** | **8** | | | |
| I think current school science is enough to meet my curiosity about the natural world | 15 | 28 | 30 | 19 | 8 | 23.7 | <0.001 | 4 |
| | **8** | **28** | **27** | **26** | **10** | | | |
| I am enjoying studying science | 10 | 25 | 33 | 19 | 13 | 43.4 | <0.001 | 4 |
| | **5** | **16** | **33** | **26** | **19** | | | |

Level 1 (N = 364) Level 3 (N = 350)

As it was shown above, students' self-perception in studying science is slightly optimistic and positive at the level 1 stage, but it has moved toward pessimistic and a more negative direction at the level 3 stage. This trend is easily observed on the basis of data from table 7.1. Many students feel science is difficult and perhaps they lose interest and confidence in science study little by little and, as a result, science becomes estranged from students.

Table 7.4 shows students' responses to the question asking whether various presented factors in learning science are helpful for them to understand science or not. It is observed from table 7.4 that students think terminology and scientific concept are more helpful than graphs and diagrams. This result is contrary to the general idea that students have a lot problems with terminology and scientific concept (see chapter 3.6) and, in many cases, graphs and diagrams are presented to promote students' understanding. There can be two kinds of explanation for this phenomenon. Firstly, it might mean that, in South Korea, students at this stage have little chance to use graphs and diagrams in studying science. Secondly, Korean students might not have much difficulty in dealing with terminology and scientific concept comparing to graphs and diagrams for some reason. It is impossible to draw clear conclusions here. Further research needs to be done about this.

**Table 7.4 Students' views about helpfulness of various factors in learning science**

| | Level | *All the time* | *Quite a lot* | *A little* | *Not at all* | $\chi 2$ | probability | df |
|---|---|---|---|---|---|---|---|---|
| Terminology | Level 1 | 9 | 42 | 41 | 6 | 36.1 | <0.001 | 2 |
| | Level 3 | 4 | 34 | 48 | 12 | | | |
| Scientific concept | Level 1 | 15 | 41 | 37 | 6 | 22.8 | <0.001 | 3 |
| | Level 3 | 6 | 43 | 41 | 9 | | | |
| Applying scientific knowledge to everyday problem | Level 1 | 17 | 38 | 35 | 8 | 10.3 | <0.05 | 3 |
| | Level 3 | 13 | 35 | 39 | 11 | | | |
| Mathematical calculation | Level 1 | 9 | 25 | 42 | 21 | 10.7 | <0.05 | 3 |
| | Level 3 | 8 | 31 | 43 | 17 | | | |
| Science laboratory | Level 1 | 31 | 40 | 22 | 5 | 88.7 | <0.001 | 3 |
| | Level 3 | 12 | 35 | 36 | 16 | | | |
| Graphs | Level 1 | 10 | 29 | 45 | 14 | 9.9 | <0.01 | 2 |
| | Level 3 | 5 | 26 | 51 | 17 | | | |
| Diagrams | Level 1 | 9 | 25 | 47 | 17 | 4.8 | n.s | 2 |
| | Level 3 | 3 | 25 | 51 | 20 | | | |
| Scientific apparatus | Level 1 | 28 | 39 | 25 | 6 | 77.1 | <0.001 | 3 |
| | Level 3 | 9 | 42 | 35 | 11 | | | |

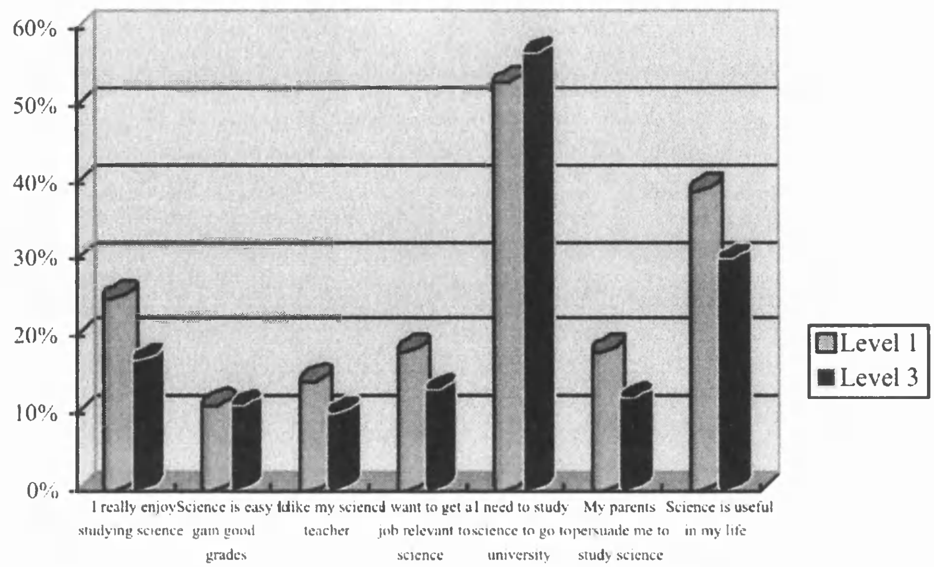
Level1 (N = 364) Level 3 (N = 350)

There is no special result about other aspects. Students' opinion that science laboratory and scientific apparatus are helpful for their studying is consistent with the result from the table 7.1. Again, as students grow older, their idea moves towards the negative direction in most cases.

## 7.3 Students' General Views about Various Aspects of Learning Science

Questions asking about students' way of learning science, reason for studying science, their favourable type of lesson or activity and so on were included in the questionnaire (see Appendix B). Figure 7.1 illustrates the reason why students study science.

Figure 7.1 The reason for studying science




From the figure 7.1, it can be seen the strongest motivation for studying science at both level 1 and 3 stage was "to go to university." This is the outcome from the South Korean educational trend that is explained in chapter 2. Almost all parents in South Korea want their children to go to a good university that guarantees a promising career and this might have a strong influence on students' mapping out their future. This tendency is more obvious at level 3 stage. This might be because level 3 is the final stage of middle school and, in relation to entering into high school, students tend to think about their future. Other main reasons for studying science were "usefulness in life" and "enjoyment in studying science".

Students' responses to the question, "What would you like to be when you are grown up?" are enumerated in table 7.5. Looking at the table 7.5, among the level 1 students, a scientist was ranked third place after a doctor and a teacher as the most favourable job that they would like to be, but among the level 3 students, scientist was ranked only middle place. Overall, 20 % of level 1 and 15% of level 3 students considered scientist as the future job.

**Table 7.5 Students' desire about future career**

| | (1) First (%) | | (2) Second (%) | | (3) Third (%) | | (1)+(2)+(3) | |
|---|---|---|---|---|---|---|---|---|
| | Level 1 | Level 3 | Level 1 | Level 3 | Level 1 | Level 3 | Level 1 | Level 3 |
| Scientist | 9 | 5 | 7 | 6 | 4 | 4 | 20 | 15 |
| lawyer | 8 | 9 | 15 | 9 | 10 | 11 | 33 | 29 |
| doctor | 20 | 12 | 16 | 14 | 14 | 11 | 50 | 37 |
| sports player | 6 | 3 | 4 | 4 | 6 | 6 | 16 | 13 |
| artist | 2 | 1 | 3 | 4 | 5 | 3 | 10 | 8 |
| musician | 4 | 6 | 7 | 9 | 4 | 5 | 15 | 20 |
| politician | 2 | 1 | 3 | 3 | 2 | 5 | 7 | 9 |
| announcer | 4 | 5 | 5 | 10 | 10 | 7 | 19 | 22 |
| businessman | 7 | 12 | 12 | 19 | 17 | 18 | 36 | 49 |
| hairdresser | 1 | 3 | 7 | 5 | 4 | 5 | 12 | 13 |
| engineer | 2 | 1 | 5 | 5 | 5 | 8 | 12 | 14 |
| teacher | 10 | 13 | 4 | 3 | 4 | 4 | 18 | 20 |

The role of science education at these ages is not just to produce scientific manpower. According to the seventh national school curriculum of Korea (see chapter 2.2), the goal of science education for age 9 to 16 is to bring up a person who has right view of nature on the basis of understanding of science knowledge and exploring skills with interest and curiosity about natural phenomena and matters. Accordingly, a well-educated student

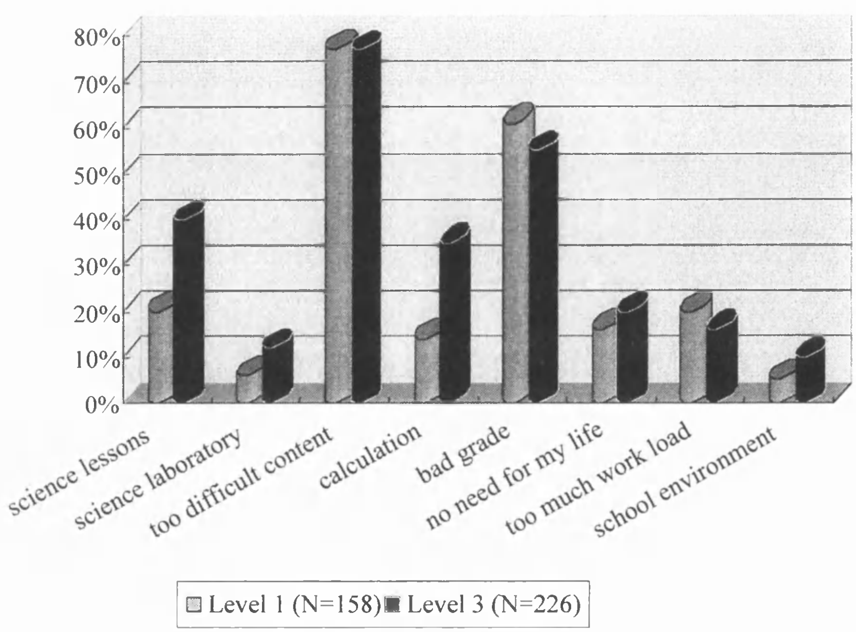
- Understands basic concepts of science through investigation of nature and applying them in everyday life.
- Develops abilities of solving the problem scientifically and applying them in everyday life.
- Develops attitudes of solving everyday problems scientifically with interest in study of science and curiosity about natural phenomena.
- Has a correct understanding of science's influence on technological development and progress of human society.

(Kim and Lee, 2003)

Thus, the main purpose of science education at middle school stage is the development of scientific literacy or producing a population that understands something of science. However, when it is considered from table 7.1 and 7.3 that students' enjoyment of studying science decreases as they grow older, the general tendency that many students tend to lose interest in science over time (Gardner, 1983) might influence the declining popularity of scientist as a future career. Then, it is necessary to make science subject popular among students in order to cultivate scientific manpower. In relation to this, there is a good example. In Scotland, Physics for many years has been the fourth most popular subject after English, Mathematics and Biology and the proportion taking Higher Physics post-16 has risen over the 1990s (Scottish Examination Board, examination statistics, 1992-1999). The popularity of the Standard Grade Physics Course seems to be the cause of increasing the number of students in Physics at the Higher Grade. The Standard Grade Physics Course was introduced in 1991. It is designed to be a course that can be seen to be both relevant and useful to people in their normal lives. Specifically, it was designed as an applications-led course where the applications come first, followed by the principles (Skryabina, 2000).

In this questionnaire, students who said they are not interested in science were asked which factor(s) had caused them to lose interest. Figure 7.2 illustrates their responses. Nearly 80% of students in both level 1 and 3 pointed out that it was the difficult content that was the cause of their losing interest in science.

Figure 7.2 The factors causing students to lose interest in scienc




Therefore, it is clear that without measures to make science more comprehensible, any attempt to attract students is destined to fail. The next biggest cause was bad grade: this is a reflection on difficulty. In relation to this, the purpose of school examination or assessment should be questioned. It is possible to list some of the likely purposes for assessment related to secondary school stages (Johnstone, 1979)

- Measuring attainment
- Giving students a motive to work
- Diagnosis and encouragement
- Giving students and teachers information about how they are doing
- Moving up to a higher stage

It would appear that the assessment was having the effect of demotivating the students. If assessment is used more formatively, for diagnosis and encouragement, then students might be encouraged more in their studies.

On the other hand, science lessons and calculations were also main causes for losing interest in science among level 3 students. Further research needs to be done to explain this, but one possible reason might be that science curriculum is more abstract and mathematical at the higher level. It has been demonstrated that pupils are attracted by a science curriculum where it is set in terms of applications that are meaningful and important pupils in the context of their life style (Reid, 1999, 2000). An abstract curriculum will have the opposite effect. In addition, abstract ideas are more difficult to understand and the possibility of working memory overload to grasp such ideas is increased (see Johnstone, 1997). The increased introduction of mathematics may also demonstrate both effects – increased abstraction and lack of realism as well as the potential for memory overload as the learner tries to handle mathematical ideas at the same time as trying to grasp scientific ideas.

Figure 7.3 The object that student usually rely on when they have difficulty in studying science

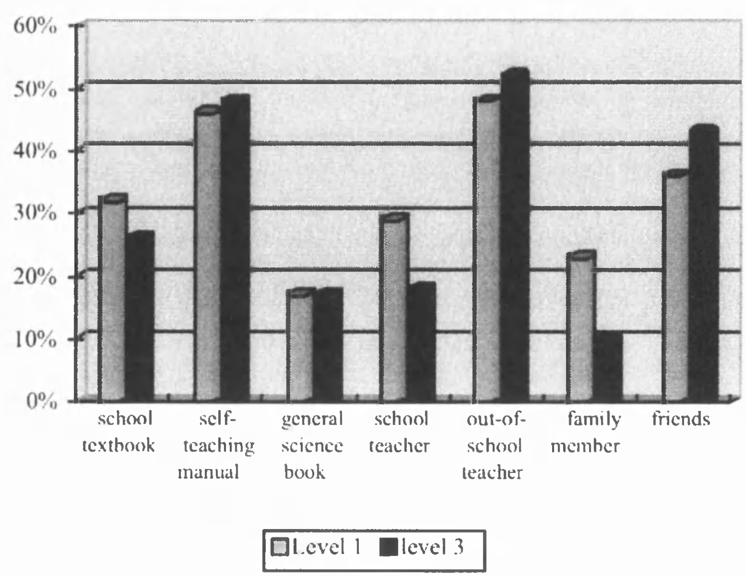


Figure 7.3 illustrates students' responses to the question, "Who (or which) do you usually rely on when you have difficulty in studying science? The figure shows that both level 1 and level 3 students usually relied on "out-of-school teacher", "self-teaching manual" and friends when they had difficulty in studying science. It seems that school science teacher and school textbooks were not very helpful and this tendency was strengthened at the level 3 stage. In particular, the fact that "out-of-school teacher" was the most influential factor of students' studying demonstrates flourish of the extra school ('hakwon') and private lessons at home in South Korea (mentioned in chapter 2). Furthermore, it reflects Korean students' belief that 'hakwon' and private lessons are more helpful than public education.

Many experts in the area of education in Korea indicate this is a phenomenon related with "*education fever*". According to Lee (2005), "*education fever can be defined as parental zeal or passion for providing their children with better chances for admission into prestigious universities*" A lot of Korean parents believe that academic credentials or higher degrees are essential to their children's social and financial success (Kim *et al.*, 2005). In a highly competitive society such as Korea, it is very difficult to get a job without having an appropriate level of credential. Although "*education fever*" may have contributed to Korean students' high academic achievements as mentioned in chapter 2.3, it has negatively influenced the public education system. Private tutoring is the most typical example showing how "*education fever*" is affecting the public education system (Kim *et al.*, 2003).

Although the quality of the public education system in Korea has been changed and improved, Korean parents do not think the public schools are helpful for students to prepare for college entrance exam. In this situation, students have few chances to participate in self-directed learning activities such as reading, public service and group project with other students. This weakens students' interest in learning and self-directed learning capacities. According to the survey of Kim and Kim (2002), more than 45.1% of students have troubles studying without private tutoring.

Tables 7.6 and 7.7 below show the general tendency of interests obtained separately for level 1 and level 3 stages, presented in declining popularity.

**Table 7.6 Topics that interest level 1 student**

| Which of the following topics interest you? | % |
|---|---|
| How we can observe a cell with a microscope? | 55 |
| How does the destruction of ozone layer affect human life? | 39 |
| How a rainbow is made? | 34 |
| Why is a air balloon lifted when it is heated? | 23 |
| What is the difference between a vegetable cell and an animal cell? | 21 |
| What condition makes the pressure and volume of gas change? | 18 |
| How the light refracts when it goes through a lens? | 17 |
| How do we classify rocks? | 15 |

**Table 7.7 Topics that interest level 3 students**

| Which of the following topics interest you? | % |
|---|---|
| How the destruction of the Amazon forest affects the ecosystem? | 42 |
| How does human blood circulate? | 38 |
| How can we observe a solar eclipse? | 37 |
| The principal of magnetic levitation train | 34 |
| How cloud and fog are formed? | 31 |
| How do we induce static electricity? | 17 |
| The difference between solids and liquids dissolving | 13 |
| How do we gain petrol from crude petroleum? | 12 |

Both level 1 and 3 students showed preference for topics related to

- Explaining a natural phenomenon; How a rainbow is made?, How does human blood circulate?, How cloud and fog are formed?
- Environmental problem; How the destruction of the Amazon forest affects the ecosystem?, How does the destruction of ozone layer affect human life?
- Application of scientific knowledge and skill; How can we observe a cell with a microscope?, How can we observe a solar eclipse?, The principal of magnetic levitation train.

On the other hand, they tend *not* to be interested in theoretical topics like

- What condition makes the pressure and volume of gas change?
- How the light refracts when it goes through a lens?
- How do we classify rocks?
- How do we induce static electricity?
- The difference between solids and liquids dissolving

This pattern of interest follows the same trend observed by Skryabina although she only looked only at Physics topics (Reid and Skryabina, 2002).

Finally, table 7.8 presents which type of lesson or activity students prefer.

**Table 7.8 Students' favourite type of lesson or activity**

| | (1) First (%) | | (2) Second (%) | | (3) Third (%) | | (1)+(2)+(3) | |
|---|---|---|---|---|---|---|---|---|
| | Level 1 | Level 3 | Level 1 | Level 3 | Level 1 | Level 3 | Level 1 | Level 3 |
| Listening to lecture | 9 | 12 | 6 | 8 | 12 | 12 | 27 | 32 |
| Discussion | 4 | 7 | 6 | 9 | 9 | 8 | 19 | 24 |
| Individual task | 1 | 1 | 2 | 1 | 4 | 4 | 7 | 6 |
| Solving exercises and problems | 3 | 2 | 6 | 5 | 7 | 8 | 16 | 15 |
| Watching science video tape | 18 | 23 | 20 | 21 | 18 | 14 | 56 | 58 |
| Making equipment or model | 10 | 13 | 26 | 20 | 18 | 20 | 54 | 53 |
| Group task | 5 | 4 | 8 | 8 | 14 | 13 | 27 | 25 |
| Laboratory | 47 | 34 | 23 | 24 | 10 | 13 | 80 | 71 |

It is obvious from the table 7.8 that students have an overwhelming preference for the laboratory. Watching science video tapes and making equipment or models are also favourite types of work among students. On the other hand, students seem to prefer group tasks to individual tasks. Of course, this does not mean these types of work preferred by students are more effective than others or they perform educational functions more effectively at the present time. However, it is clear that, in order to achieve affective as well as cognitive objectives, students' preference should be taken into consideration when science curriculum is developed.

## 7.4 Summary

1. The majority of level 1 and level 3 students thought
   - Science is useful
   - Science topics are relevant to them
   - Laboratory work is good fun and they learn a lot from laboratory work
   - Science is difficult
   - A scientist is responsible, clever, valuable to society, involved with people, a hard worker and doing a safe job
   - A scientist is not popular

2. A lot of students who thought
    - They enjoy their studies
    - They are coping with their study very well
    - Science is an important subject for their life
    - They are getting better at science
    - Current school science is enough to meet their curiosity about the natural world
    - They would like to be a scientist changed their minds toward a more pessimistic and negative direction during their middle school life.

3. It was observed that the strongest motivation for studying at both level 1 and 3 stages was "to go to university" which might be a kind of product of South Korean society.

4. It was found that the overwhelming majority of students at level 1 and 3 stages lost their interest in science due to difficulty of learning science and school science teacher and school textbooks were not very helpful to students' studying science.

5. Both level 1 and 3 students tend to like topics related to explaining a natural phenomenon, environmental problem and application of scientific knowledge and skill. A great number of students mentioned laboratory work as their most favourite type of lesson.

# Chapter Eight

# The Learning of Science Relationships between Cognitive and Affective Aspects

In this chapter, the relationship between student working memory space and attitudes is discussed. Comparisons are made between students with high, middle and low working memory capacity and their interest in science, way of learning, reason for studying science as well as other characteristics.

## 8.1 The Result of Figural Intersection Test

Table 8.1 shows students' performance in the Figural Intersection Test

**Table 8.1 Students' performance in Figural Intersection Test**

| | | N | Minimum | Maximum | Mean | S.D |
|---|---|---|---|---|---|---|
| WMS | Level 1 | 364 | 1.50 | 8.00 | 5.6 | 1.62 |
| | Level 3 | 350 | 2.00 | 9.00 | 5.7 | 1.55 |

Although correlation was used to explore any relationship between working memory space (WMS) and the responses to questions in the attitude survey, it is also helpful to divide each level of students into groups according to their working memory. For this purpose, both level 1 and level 3 students were divided into three groups; low, middle and high working memory capacities. The same grouping system was used for level 1 and 3 since the difference of score between level 1 (age 12) and 3 (age 14) is very small. Students with a score of 7 or more were classified as having high working memory capacity. Students with scores between 5 and 7 were classified as having intermediate working memory capacity. The rest with 5 or less than 5 were classified as having low working memory capacity. The result of classification is shown in the table 8.2. The division into the three groups *illustrates* the relationship between working memory and attitude responses while correlation shows whether the pattern is *significant* or not.

While the Figural Intersection Test is known to be fairly accurate (Johnstone and Elbanna, 1989), the results must be treated with caution because only one test cannot guarantee 100% accuracy. For more valid measurement, it is recommended to use two tests, one visual and one symbolic, and compare results between the two tests. However, time did not allow the use of two tests. Of even greater importance, it is important to note that the scores should not be regarded as absolute values. In this research, they are treated in a *relative* sense.

**Table 8.2 The classification of the students into working memory capacity groups**

| **Group** | | **Number of students** |
|---|---|---|
| **Level 1 (N=364)** | High | 100 |
| | Middle | 166 |
| | Low | 98 |
| **Level 3 (N=350)** | High | 95 |
| | Middle | 172 |
| | Low | 83 |

## 8.2 The Correlation between Working Memory Space and Attitudes

In order to investigate relationships between WMS and attitudes toward science, correlation coefficients were calculated. In this research, Kendall's tau-b method was used in that it handles categorical data well. Pearson correlation is inappropriate in that the attitude data is not interval data with any approximation to normality while the Spearman's rho does not handle ties (many in the same category) very well. Kendall's tau-b does not assume normality and handles ties well.

The correlation coefficients between WMS and attitudes towards studies in science are collected in table 8.3. As can be seen in table 8.3, the WMS in general is not highly correlated with attitudes although, with the large samples here, high significance is observed. However, several items are worth consideration. Students' enjoyment, the extent of easiness in doing science and the impression that science is interesting show significant relationships to working memory capacity at both level 1 and 3. In other words, students who have high working memory capacity tend to enjoy science studies (in table 8.3, minus correlation means the higher working memory capacity students have, the more they enjoy their studies because the higher grade was given to the negative sentence when the correlation coefficient was calculated) and think science is easy and interesting. Furthermore, WMS is likely to be more correlated with affective elements of attitude (eg, "I enjoy my studies", "Science is interesting") than cognitive elements (eg, "Science topics are relevant to me", "Laboratory work is good fun"). In the case of level 1, the idea about usefulness of science is also significantly correlated with WMS so that students who have high working memory capacity are inclined to think science is useful.

**Table 8.3 Correlations between WMS and attitudes towards studies in science**

| Correlations between WMS and attitudes towards studies in science | | Level 1 | Level 3 |
|---|---|---|---|
| I do not enjoy my studies | Correlation Coefficient | -.138** | -.139** |
| | Sig. (2-tailed) | .001 | .001 |
| | N | 362 | 349 |
| I find science easy | Correlation Coefficient | .138** | .102* |
| | Sig. (2-tailed) | .001 | .014 |
| | N | 363 | 349 |
| Science is not useful | Correlation Coefficient | -.109** | -.031 |
| | Sig. (2-tailed) | .008 | .454 |
| | N | 364 | 348 |
| Science is interesting | Correlation Coefficient | .126** | .118** |
| | Sig. (2-tailed) | .002 | .004 |
| | N | 363 | 350 |
| Science topics are relevant to me | Correlation Coefficient | .069 | .073 |
| | Sig. (2-tailed) | .086 | .075 |
| | N | 361 | 349 |
| There is not enough work | Correlation Coefficient | .039 | .076 |
| | Sig. (2-tailed) | .331 | .063 |
| | N | 363 | 347 |
| Laboratory work is not good fun | Correlation Coefficient | -.049 | -.067 |
| | Sig. (2-tailed) | .239 | .103 |
| | N | 362 | 349 |
| I learn a lot from laboratory work | Correlation Coefficient | .029 | .051 |
| | Sig. (2-tailed) | .475 | .216 |
| | N | 361 | 349 |
| My text books are not helpful | Correlation Coefficient | -.022 | .050 |
| | Sig. (2-tailed) | .585 | .220 |
| | N | 363 | 347 |

Note in this table 8.3 and in the remaining tables of this chapter.

*. correlation is significant at the 0.05 level (2-tailed)

**. correlation is significant at the 0.01 level (2-tailed)

Table 8.4 presents the correlations between WMS and attitudes towards scientist. Judging from table 8.4, in general, correlations between students' image about scientist and WMS are very low. WMS is regarded as important variable of learning difficulty (discussed in chapter three). Therefore, it might be suggested that students build up perception of scientist *independent* of their experience of learning science and understanding of scientific knowledge. A socially common notion about scientist or the idea of important reference person or group such as teacher, parents and friends might be an influential factor in forming beliefs about scientists.

**Table 8.4 Correlations between WMS and attitudes towards scientists**

| Correlations between WMS and attitudes towards scientists | | Level 1 | Level 3 |
|---|---|---|---|
| irresponsible | Correlation Coefficient | -.028 | .021 |
| | Sig. (2-tailed) | .495 | .610 |
| | N | 362 | 350 |
| dull | Correlation Coefficient | .041 | -.039 |
| | Sig. (2-tailed) | .334 | .368 |
| | N | 363 | 349 |
| poor | Correlation Coefficient | .005 | -.105* |
| | Sig. (2-tailed) | .905 | .011 |
| | N | 360 | 348 |
| worthless to society | Correlation Coefficient | .020 | -.084* |
| | Sig. (2-tailed) | .633 | .049 |
| | N | 363 | 348 |
| not popular | Correlation Coefficient | .076 | .032 |
| | Sig. (2-tailed) | .060 | .440 |
| | N | 363 | 349 |
| detached from people | Correlation Coefficient | .006 | .051 |
| | Sig. (2-tailed) | .876 | .209 |
| | N | 362 | 349 |
| not a hard worker | Correlation Coefficient | .024 | -.048 |
| | Sig. (2-tailed) | .554 | .255 |
| | N | 363 | 349 |
| doing a safe job | Correlation Coefficient | .060 | .072 |
| | Sig. (2-tailed) | .138 | .086 |
| | N | 362 | 348 |

Apart from the results from table 8.4, it is necessary to think whether school science education in South Korea provides students with proper information about a scientist. According to some research performed in South Korea (Song, Pak and Jang, 1992), South Korean middle school students mentioned Edison, Einstein, Marie Curie and Newton as the scientists whom they respected, demonstrating a lack of any contemporary role models. This means students' perception of scientists are dominated by the great people of the more distant past. It might be necessary for science education to talk more about what a biologist or physicist does: that is, the stories of everyday science and scientists, contemporary issue in science and actual working practices of scientists.

The questionnaire included questions asking students' self-perception and views about various factors of studying science. Table 8.5 below shows the correlation coefficients between WMS and students' self-perceptions in studying science.

**Table 8.5 Correlations between WMS and students' self-perception in studying science.**

| Correlations between WMS and self-perception in studying science | | Level 1 | Level 3 |
|---|---|---|---|
| I am coping with my science work very well | Correlation Coefficient | -.136** | -.079 |
| | Sig. (2-tailed) | .001 | .061 |
| | N | 364 | 350 |
| Science is an important subject for my life | Correlation Coefficient | -.178** | -.132** |
| | Sig. (2-tailed) | .000 | .002 |
| | N | 364 | 350 |
| I am getting better at science | Correlation Coefficient | -.132** | -.101* |
| | Sig. (2-tailed) | .001 | .016 |
| | N | 362 | 350 |
| My understanding about the natural world is progressing by virtue of studying science | Correlation Coefficient | -.106** | -.107* |
| | Sig. (2-tailed) | .010 | .011 |
| | N | 361 | 347 |
| I think current school science is enough to meet my curiosity about the natural world | Correlation Coefficient | -.092* | -.080 |
| | Sig. (2-tailed) | .023 | .055 |
| | N | 362 | 347 |
| I am enjoying studying science | Correlation Coefficient | -.175** | -.150** |
| | Sig. (2-tailed) | .000 | .000 |
| | N | 362 | 350 |

In this question, five (strongly agree, agree, neutral, disagree, strongly disagree) responses were invited (see Appendix B) and the highest grade was given to the scale, "strongly disagree." Therefore, a negative correlation coefficient means the higher student's working memory capacity is, the more (s)he agrees with the sentence.

The following picture has emerged from the table 8.5: when compared to their peers with low working memory capacity, students who have high working memory capacity tend to feel that

- They are coping with their science work very well.
- Science is an important subject for their life.
- They are getting better at science.
- Their understanding about the natural world is progressing by virtue of studying science.
- Current school science is enough to meet their curiosity about the natural world.
- They are enjoying studying science.

This tendency is stronger for the level 1 students.

While table 8.5 shows that none of the correlation values is very high, most are significant statistically. Correlation does not necessarily reflect cause and effect, but it is of some concern that many of the positive self-perceptions noted in this table are related to higher working memory. While it has been established that high working memory brings cognitive advantages (eg Johnstone and Elbanna, 1989), the data from this table suggest that high working memory may also bring (or be related to) important attitudinal advantages in studying science.

The correlations between WMS and students' views about various factors of learning science can be seen in table 8.6. For this question, four (all the time, quite a lot, a little, not at all) responses were offered (see Appendix B) and the highest code was given to the scale, "not at all." Therefore, a negative correlation means the higher student's working memory capacity is, the more each item has helped him/her to understand science.

**Table 8.6 Correlations between WMS and students' views about various factors of learning science**

| Correlations between WMS and views about various aspects of learning science | | Level 1 | Level 3 |
|---|---|---|---|
| Terminology | Correlation Coefficient<br>Sig. (2-tailed)<br>N | -.024<br>.573<br>359 | -.014<br>.753<br>347 |
| Scientific concept | Correlation Coefficient<br>Sig. (2-tailed)<br>N | -.138**<br>.001<br>358 | -.106*<br>.015<br>347 |
| Applying scientific knowledge to everyday problems | Correlation Coefficient<br>Sig. (2-tailed)<br>N | -.160**<br>.000<br>354 | -.069<br>.108<br>345 |
| Mathematical calculation | Correlation Coefficient<br>Sig. (2-tailed)<br>N | -.061<br>.149<br>354 | -.043<br>.318<br>346 |
| Science laboratory | Correlation Coefficient<br>Sig. (2-tailed)<br>N | -.056<br>.187<br>356 | -.107*<br>.012<br>346 |
| Graphs | Correlation Coefficient<br>Sig. (2-tailed)<br>N | -.055<br>.192<br>355 | -.075<br>.085<br>346 |
| Diagrams | Correlation Coefficient<br>Sig. (2-tailed)<br>N | -.015<br>.726<br>356 | -.105*<br>.016<br>346 |
| Scientific apparatus | Correlation Coefficient<br>Sig. (2-tailed)<br>N | -.048<br>.260<br>353 | -.119**<br>.006<br>341 |

In most cases, the correlation is weak. However, the correlation between working memory space and helpfulness of scientific concept is significant at both level 1 and 3. In other words, scientific concept is likely to be an obstacle to understand science for students with low working memory capacity. On the other hand, science laboratory, diagrams and scientific apparatus are not inclined to be helpful to level 3 students with low working memory capacity while applying scientific knowledge to everyday problem is not likely to be helpful to level 1 students with low working memory capacity.

## 8.3 Working Memory Capacity about Various Aspects of Learning Science

In order to investigate whether working memory space influences several factors related to studying science, students with high, middle and low working memory capacity were compared. All figures are indicated as percentages for clarity but the frequency numbers are used for calculating the chi-square statistic. Some students failed to answer so adding up all the figures sometimes does not always come to one hundred.

The followings are some results that show significant differences between high, middle and low working memory space students in some aspects of learning science. All the results are can be seen in Appendix C.

First of all, table 8.7 shows high, middle and low working memory students' response to the question, "Are you interested in science?" and table 8.8 presents chi- square values for comparison between high and low working memory capacity students.

**Table 8.7 High, middle and low working memory students' responses: Are you interested in science?**

| Are you interested in science? | Level 1 | | | Level 3 | | |
|---|---|---|---|---|---|---|
| | High (N=100) | Mid (N=166) | Low (N=98) | High (N=95) | Mid (N=172) | Low (N=83) |
| YES | 66% | 55% | 39% | 48% | 36% | 22% |
| NO | 33% | 42% | 57% | 53% | 64% | 78% |

**Table 8.8 Comparison between high and low working memory students about their interest in science**

| Are you interested in science? | $\chi^2$ | probability | df | Favoured |
|---|---|---|---|---|
| Level 1 (high-low) | 13.4 | <0.001 | 1 | high |
| Level 3 (high-low) | 8.4 | <0.01 | 1 | high |

It is found that high working memory students are significantly more interested in science than low working memory students. On the other hand, tables 8.9 and 8.10 demonstrate how students have usually studied science so far against all students and high, middle and low working memory students separately.

**Table 8.9 High, middle and low working memory students' responses:**

**How have you usually studied science so far?"**

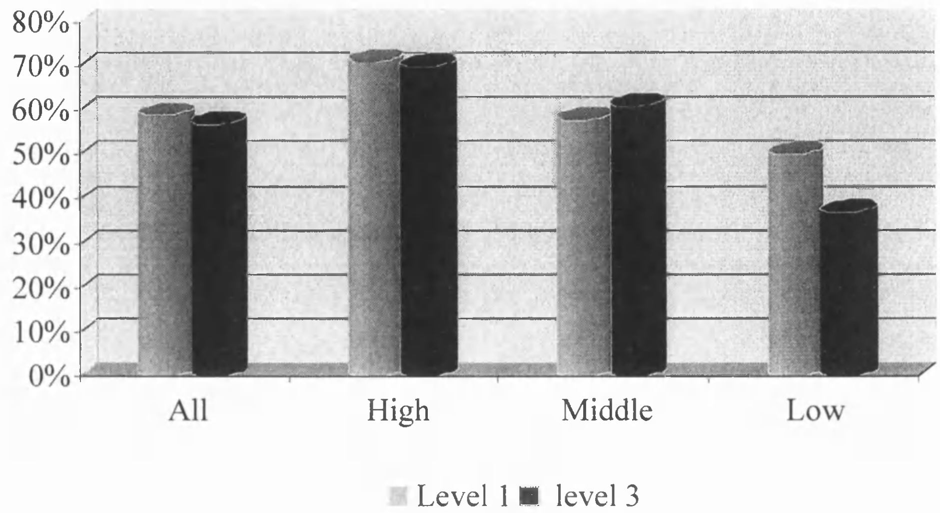
| | | I have tried to **understand** science knowledge such as concepts, rules, theory as much as I can | I have tried to **memorize** science knowledge such as concepts, rules, theory as much as I can |
|---|---|---|---|
| Level 1 | **All (N=364)** | **59%** | **33 %** |
| | **High (N=100)** | 71% | 24 % |
| | **Mid (N=166)** | 58 % | 34 % |
| | **Low (N=98)** | 50 % | 39 % |
| Level 3 | **All (N=350)** | **57 %** | **33%** |
| | **High (N=85)** | 70 % | 25% |
| | **Mid (N=172)** | 61 % | 31% |
| | **Low (N=78)** | 37 % | 45 % |

**Table 8.10 Comparison between high and low working memory students about their way of learning**

| **The way of learning** | $\chi^2$ | **probability** | **df** |
|---|---|---|---|
| **Level 1(high-low)** | 6.9 | <0.01 | 1 |
| **Level 3(high-low)** | 12.0 | <0.001 | 1 |

It can be seen from table 8.9 and 8.10 that students who have high working memory capacity tend to try to understand science knowledge such as concepts, rules, theory as much as they can while students who have low working memory capacity tend to try to memorize science knowledge. Moreover, in high WMS students' group, there is no significant difference between percentages of level 1 and 3 students who said they have tried to understand science (and, therefore, they have tried to memorize science). However, in low working memory students' group, the data show that the difference is not small. Thus, it can be thought that not a few students who had tried to understand science at lower level said they did not try to understand science any more at higher level. This might mean the lower WMS students have tended to turn their way of studying science to memorization. Figure 8.1 below shows this more clearly.

Figure 8.1 The comparison of the difference between percentages of level 1 and 3 students who have tried to understand science against high, middle and low WMS groups




According to the information processing model, the student's working memory is easily overloaded in learning situation unless (s)he has appropriate chunking skill. This overload of working memory happens to low WMS students more often and they have more difficulty in studying science than high WMS students. What might be the result of working memory overload?

One clue can be obtained from Johnstone and Wham's research (1982) about the effects of working memory overload in practical work. According to their research, during a laboratory experiment, students' working memory can be easily overloaded because too many things are required simultaneously to be manipulated cognitively. In the situation of unstable overload, they observed that students' action tend to:

- Adopt recipe following
- Concentrate on one part excluding the rest
- Show busy random activity
- Copy the actions of others
- Adopt the role of 'recorder'

In other words, in general, when students are faced with working memory overload, they might come to give up understanding which requires active thinking in order to avoid an unstable state. They might attend the class from a mere sense of obligation and adopt memorization as the alternative way of learning simply to obtain a good examination mark. Consequently, their interest in science may fall off.

Figure 8.2 The reason that high, middle and low working memory students study science at level 1

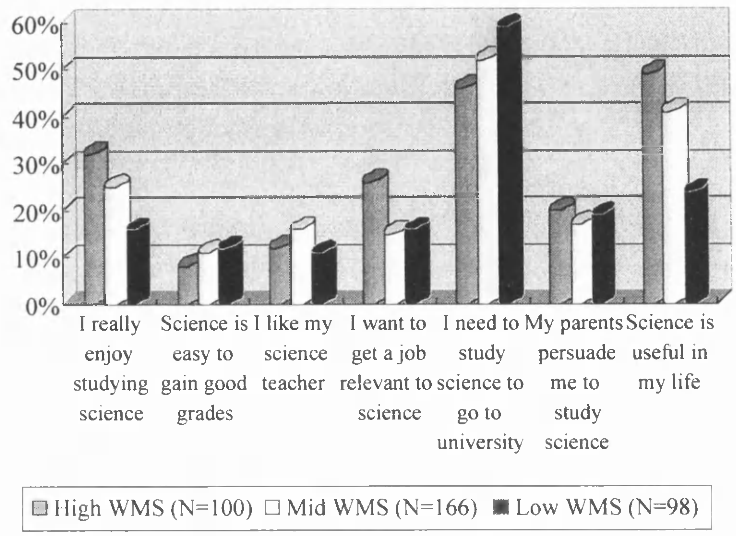
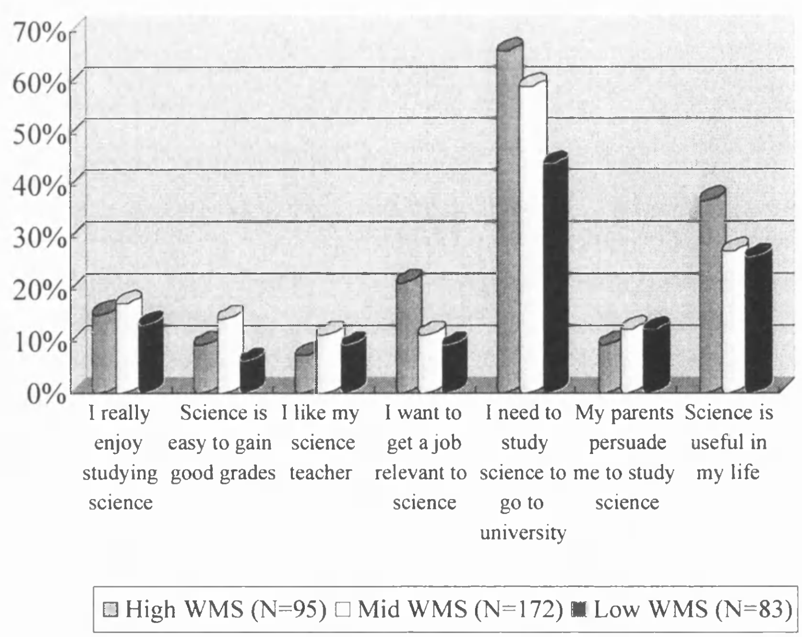



Figure 8.3 The reason that high, middle and low working memory students study science at level 3




Secondly, figure 8.2 and 8.3 above illustrate the reason that high, middle and low WMS students study science. Looking at the figure 8.2, at level 1 stage, the percentage of students who pointed out "I really enjoy studying science." or "science is useful in my life" as the reason of studying science was higher in high working memory space students' group while the percentage of students who pointed out "I need to study science to go to university." or "science is easy to gain good grades." was higher in low WMS students' group.

According to the *Theory of Planned Behaviour* (Ajzen, 1985), a person's behaviour can be influenced by the person's intention to perform that behaviour. A person's intention to behave can be predicted in terms of

- Attitudinal factors; the person's positive or negative feelings about engaging in the behaviour
- Subjective norm factors; the person's perception of the social pressures and norms to perform or not to perform
- Perceived behavioural control factors; the person's belief as to how easy or difficult performance of the behaviour is likely to be

Applying this theory to interpreting figure 8.2, attitudinal factors ("I really enjoy studying science", "science is useful in my life") might influence high WMS students' motive to study science more than low WMS students' motive while perceived behavioural factors ("science is easy to gain good grades") and subjective norm factors ("I need to study science to go to university") might influence low WMS students' motive more than high WMS students' motive.

On the other hand, as it can be seen in figure 8.3, a different pattern appeared at the level 3 stage. The fact that they are on the final stage at middle school and going on to high school might make students think about their future more than before. In this situation, high WMS students might be more influenced by subjective norm factors such as "I need to study science to go to university." and "I want to get a job related to science" than low WMS students because they consider scientist as a future job more than low working memory space students (See table 8.11 and 8.12 below)

Comparing figure 8.3 with figure 8.2, it can be seen, at the level 3 stage, that attitudinal factors such as "I really enjoy studying science" and "science is useful in my life" influenced considerably less high working memory students' motive to study science than at the level 1. However, this tendency does not appear among low working memory students. In order to explain this phenomenon, further research should be done, but it is clear that the experience of middle school science tends to make all students with high, middle and low working memory capacity lose their attitudinal motive to study science. Lastly, table 8.11 and 8.12 show comparisons between high, middle and low working memory student about their job desire at both level 1 and 3. The table shows the percentage of pupils who chose each career as first choice, second choice or third choice.

**Table 8.11 Comparison between high (N=100) and middle (N=166) and low (N=98) working memory students about their job desire in level 1 stage.**

| | (1) First (%) | | | (2) Second (%) | | | (3) Third (%) | | | (1)+(2)+(3) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Mid | Low | High | Mid | Low | High | Mid | Low | High | Mid | Low |
| scientist | 17 | 8 | 4 | 11 | 7 | 3 | 3 | 6 | 1 | 31 | 21 | 8 |
| lawyer | 8 | 6 | 11 | 15 | 15 | 13 | 7 | 10 | 12 | 30 | 31 | 36 |
| doctor | 20 | 18 | 22 | 15 | 18 | 14 | 11 | 15 | 14 | 46 | 51 | 50 |
| sports player | 8 | 4 | 7 | 4 | 2 | 6 | 4 | 6 | 8 | 16 | 12 | 21 |
| artist | 1 | 2 | 1 | 5 | 2 | 3 | 5 | 6 | 3 | 11 | 10 | 7 |
| musician | 4 | 5 | 4 | 5 | 7 | 9 | 4 | 4 | 4 | 13 | 16 | 17 |
| politician | 0 | 2 | 2 | 5 | 2 | 3 | 1 | 1 | 3 | 6 | 7 | 8 |
| announcer | 2 | 5 | 5 | 1 | 7 | 7 | 9 | 3 | 6 | 12 | 18 | 18 |
| businessman | 9 | 7 | 5 | 10 | 14 | 10 | 19 | 17 | 18 | 38 | 38 | 33 |
| hairdresser | 1 | 1 | 1 | 5 | 7 | 9 | 2 | 5 | 5 | 8 | 13 | 15 |
| engineer | 0 | 2 | 2 | 5 | 5 | 5 | 11 | 3 | 2 | 16 | 10 | 9 |
| teacher | 5 | 14 | 9 | 2 | 4 | 4 | 3 | 4 | 5 | 10 | 22 | 18 |

**Table 8.12 Comparison between high (N=95) and middle (N=172) and low (N=83) working memory students about their job desire in level 3 stage**

| | (1) First (%) | | | (2) Second (%) | | | (3) Third (%) | | | (1)+(2)+(3) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Mid | Low | High | Mid | Low | High | Mid | Low | High | Mid | Low |
| scientist | 8 | 4 | 2 | 10 | 5 | 4 | 2 | 5 | 6 | 20 | 14 | 12 |
| lawyer | 7 | 10 | 8 | 7 | 11 | 10 | 17 | 11 | 5 | 31 | 32 | 23 |
| doctor | 19 | 10 | 10 | 14 | 13 | 16 | 11 | 13 | 10 | 44 | 36 | 36 |
| sports player | 3 | 4 | 4 | 3 | 6 | 2 | 3 | 4 | 15 | 9 | 14 | 21 |
| artist | 1 | 1 | 4 | 5 | 4 | 2 | 0 | 5 | 0 | 6 | 10 | 6 |
| musician | 5 | 5 | 8 | 5 | 11 | 10 | 0 | 8 | 6 | 10 | 24 | 24 |
| politician | 0 | 1 | 2 | 4 | 2 | 6 | 8 | 4 | 5 | 12 | 7 | 13 |
| announcer | 4 | 6 | 2 | 10 | 14 | 4 | 8 | 4 | 10 | 22 | 24 | 16 |
| businessman | 8 | 14 | 13 | 24 | 17 | 19 | 17 | 19 | 17 | 49 | 50 | 49 |
| hairdresser | 0 | 4 | 5 | 1 | 8 | 2 | 8 | 2 | 7 | 9 | 14 | 14 |
| engineer | 1 | 2 | 0 | 5 | 3 | 7 | 10 | 11 | 1 | 16 | 16 | 8 |
| teacher | 13 | 14 | 12 | 3 | 2 | 5 | 8 | 3 | 0 | 24 | 19 | 17 |

It was observed that high working memory students select scientist as a future job more frequently than low working memory students. Furthermore, the difference of the proportion taking scientist as their future career between high and low working memory students is large when compared to other jobs. This trend is somewhat weaker at level 3 stage, but scientist and occupations related to science like doctor and engineer seem to be more popular among high WMS students than low WMS students.

There can be two possible reasons for this situation. Firstly, the nature of science can be very cognitive and theoretical. The success in studying science depends considerably on working memory capacity (This is discussed in chapter 3.6 'Working Memory Overload and Learning Difficulty'). Therefore students who have low working memory capacity might lose their interest and confidence more than their peers with high working memory and this might influence their decision about a future profession. Secondly, current South Korean science education might have encouraged high working memory students more than low working memory students. It might be the problem of a curriculum which provides too abstract and difficult content, and, therefore, demands high working memory capacity. It might be also the problem of teacher who teaches science without careful consideration of working memory's limit.

## 8.4 Summary

1. In general, working memory space is more correlated with students' attitudes towards studies in science more than attitude towards scientists.

2. When compared to students with high WMS, students who have low WMS tend to feel that

   - They cannot cope with science work
   - Science is not very important for their life
   - They are not getting better at science
   - Their understanding about natural world is not progressing through studying science
   - Current school science is not enough to meet their curiosity about the natural world
   - They are not enjoying studying science.

3. Students who have high WMS tend to try to understand science knowledge such as concepts, rules, theory as much as they can while students who have low WMS tend to try to memorize science knowledge.

4. When compared to other jobs such as lawyer, doctor and businessman etc, a scientist was considered as a future career among high working memory students more than low working memory students.

# Chapter Nine

# Conclusions and Suggestions

It has been thought that attitudes are not only very influential variables in successful learning but also may have far-reaching consequences for careers, lifestyles and society. Previous work (Reid and Skryabina, 2002 a and b) suggested the following:

- Two factors are influential in attracting and retaining the learners;

  (a) Quality curriculum and teaching – do the students have a positive learning experience?
  (b) The perceived status of physics (or science) and career prospects arising from physics (or science) – is it worth studying physics (or science)?

- An application-led course is powerful way of developing positive attitudes.

On the other hand, many researchers have paid much attention to the processes of human learning and the matters of learning difficulty since Johnstone's information processing model (1993) was introduced. One of the outcomes of this trend is the practical suggestion that, in science education, the working memory space is easy to overload and the working memory demand of much learning strongly influences success.

This study began with the intention of looking at cognitive and attitudinal aspects of learning science together. In order to do that, it was decided to investigate the relationship between working memory space and attitudes.

## 9.1 Conclusions

An analysis of the data from the working memory test and the questionnaire suggests the following in relation to South Korean students' attitudes towards science.

1. In general, South Korean middle school students are positive towards the cognitive elements of attitudes towards science and scientist (e.g. "Science topics are relevant to me", "A scientist is valuable to society."). However, they are negative towards affective elements (e.g. "I enjoy my studies", "A scientist is popular"). This can be a kind of

compartmentalization. Their feeling on school science might be inconsistent with beliefs that they have about science. On the other hand, from the correlation analysis between working memory space and attitudes, it can be seen that affective elements of attitudes and students' self-perception tend to be more correlated with working memory space than cognitive elements. Compared to students with high working memory capacity, students who have low working memory capacity tend to:

- Lose their interest in science.
- Feel science is difficult.
- Have low confidence about studying science.

In conclusion, it is possible to say that South Korean middle school students have negative feelings towards studying science and this might be related to working memory space, which is easy to overload in the learning situation. It seems that they see the significance and importance of science but they do not really enjoy their experiences in learning in science.

2. The prominent characteristics of South Korean middle school students' ideas related to studying science are as it follows:

   - They have an overwhelming preference for laboratory work.
   - The strongest motivation for studying science is "to go to university".
   - The main factors that make them to lose interest in science are "too difficult content" and "bad grade".

3. When compared to students with high working memory capacity, students who have low working memory capacity tend to;
   - Depend on memorization when they study science.
   - Be less likely to consider science-based careers.
   - Be less motivated to study science by attitudinal factors ("I really enjoy studying science", "Science is useful in my life").

## 9.2 Suggestion for Teaching

If teachers want to develop students' attitudes toward science, they should

- Take learning difficulties (students' working memory limit) into consideration.
- Take factors that encourage students to study science, such as their favourite type of lesson and their motivation, into consideration.
- Pay careful attention to the way of presenting teaching materials as well as its contents to avoid overload of working memory space.

## 9.3 Recommendation for further study

This was a small exploratory study. Many studies have looked at working memory capacity and its implications for learning while many studies have focused on the importance of attitudes. This was an attempt to bring together these two areas. While some interesting observations can be made, this work offers a range of questions needing further exploration.

1. The results of the present study might only reflect the South Korean middle school educational situation. It would be interesting to examine relationship between working memory space and students' attitudes in other countries or other levels or separate disciplines like physics, chemistry etc.

2. The results of this research suggest that low working memory students tend to more depend on memorization than high working memory students. It needs to be explored how to help low working memory students to understand science.

3. There are other cognitive factors believed to have an important influence on student's performance in studying science; field-dependence/independence, convergency/divergency, visual-spatial ability and so on. The investigation of their relationship with student's attitudes could provide teachers with new insight into science education.

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# Appendixes

# Appendix A

## Figural Intersection Test

# Figure Intersection Test

Name: ____________________ Sex: Boy Girl

This is a test of your ability to find the overlap of a number of simple shapes.

There are two sets of simple geometric shapes, one on the right and the other on the left. The set on the left contains the same shapes (as on the right) but overlapping, so that there exists a common area which is inside all of the shapes.

***Look for*** and ***shade*** in the common ***area of overlap***.

***Note these points:***

(1) The shapes on the left may differ in size or position from those on the right, but they match in *shape* and *proportions*.

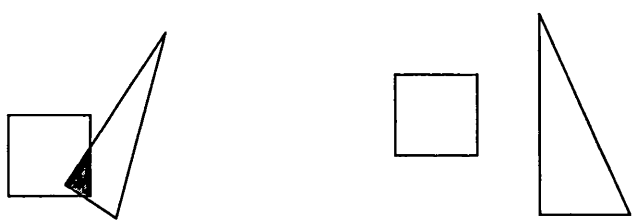
(2) In some items on the left some extra shapes appear which are not present in the right hand set, and which do not form a common area of intersection with all of the other shapes. These are present to mislead you to ignore them.

(3) The overlap should be shaded clearly by using a pen.

(4) The results of this test will not affect your schoolwork in any way.

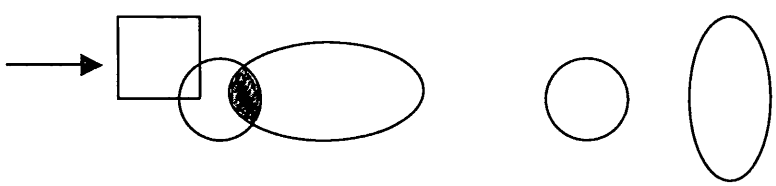
Here are some samples to get you started.

***Example (1):***

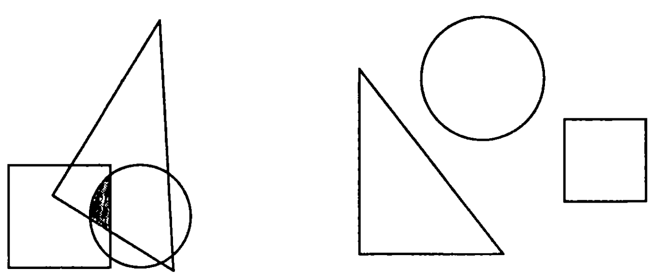


***Example (2):***

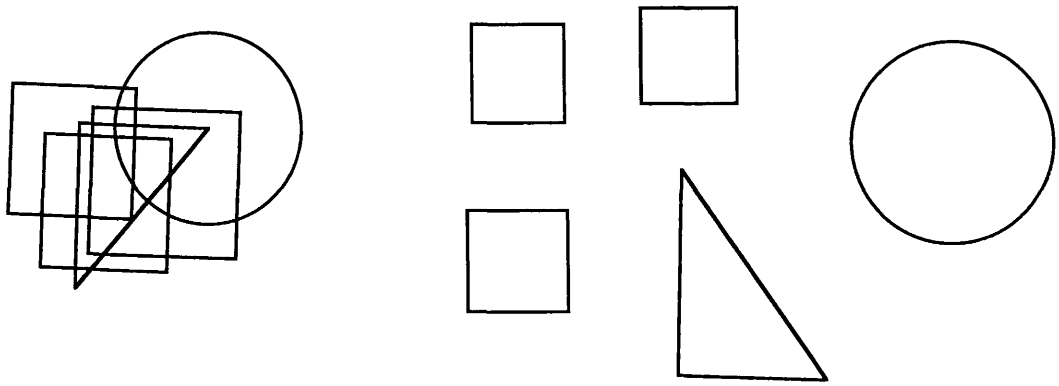
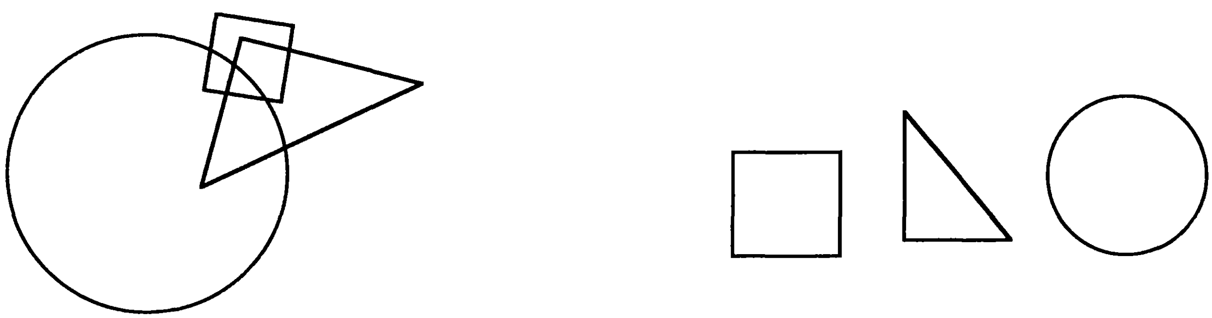
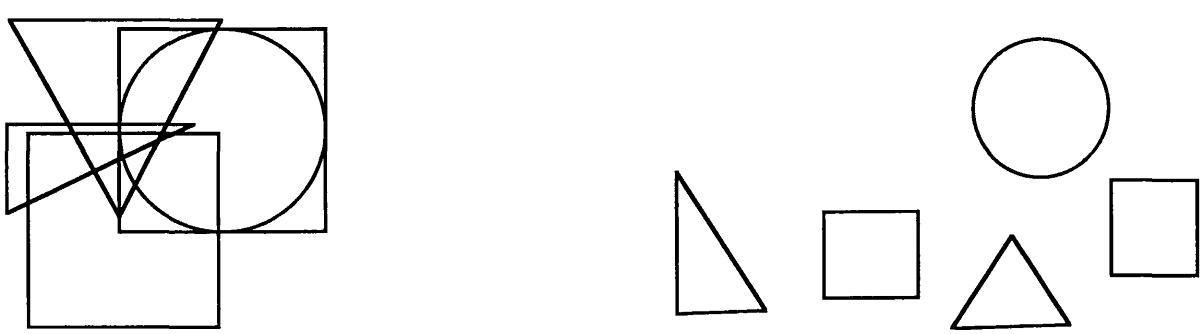
Irrelevant shape put in to confuse you!

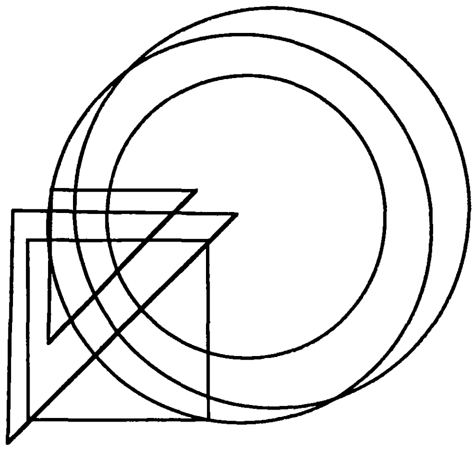
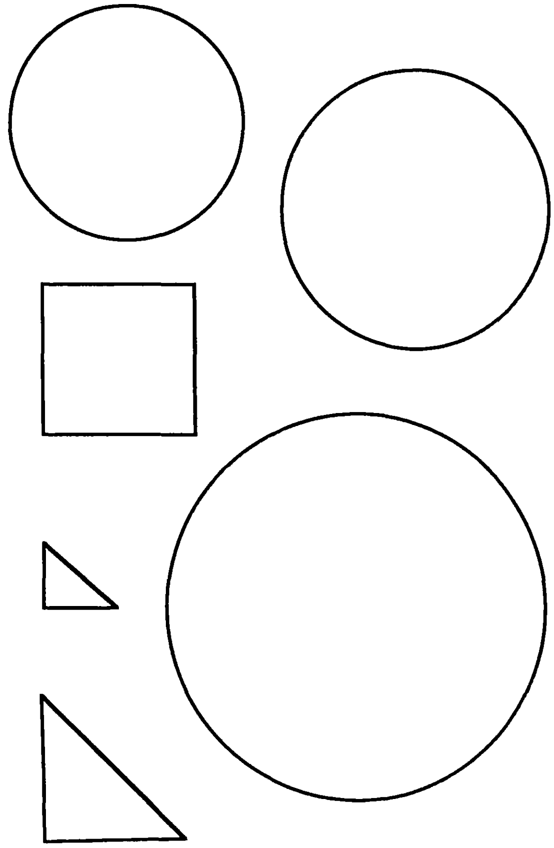
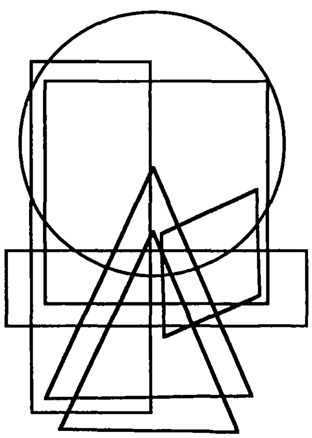
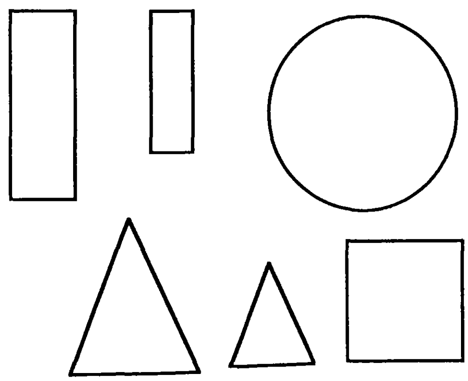
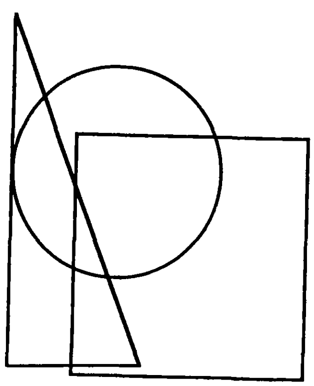
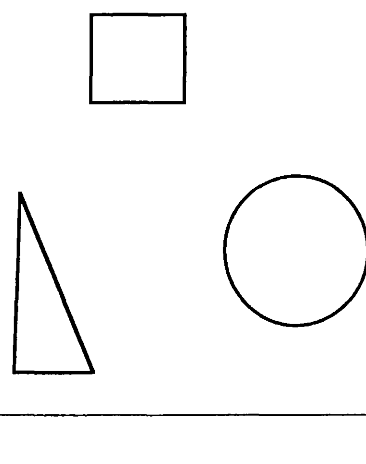


***Example (3):***



Now attempt each of the items on the following sheets:

| | |
|---|---|
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |

| | | |
|---|---|---|
| 5 |  |  |
| 6 |  |  |
| 7 |  |  |

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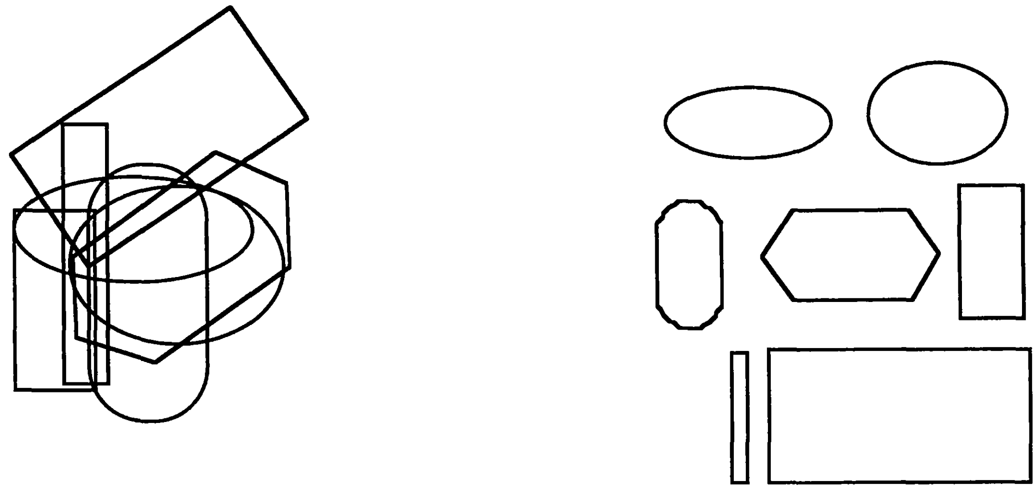
| 8 |  |
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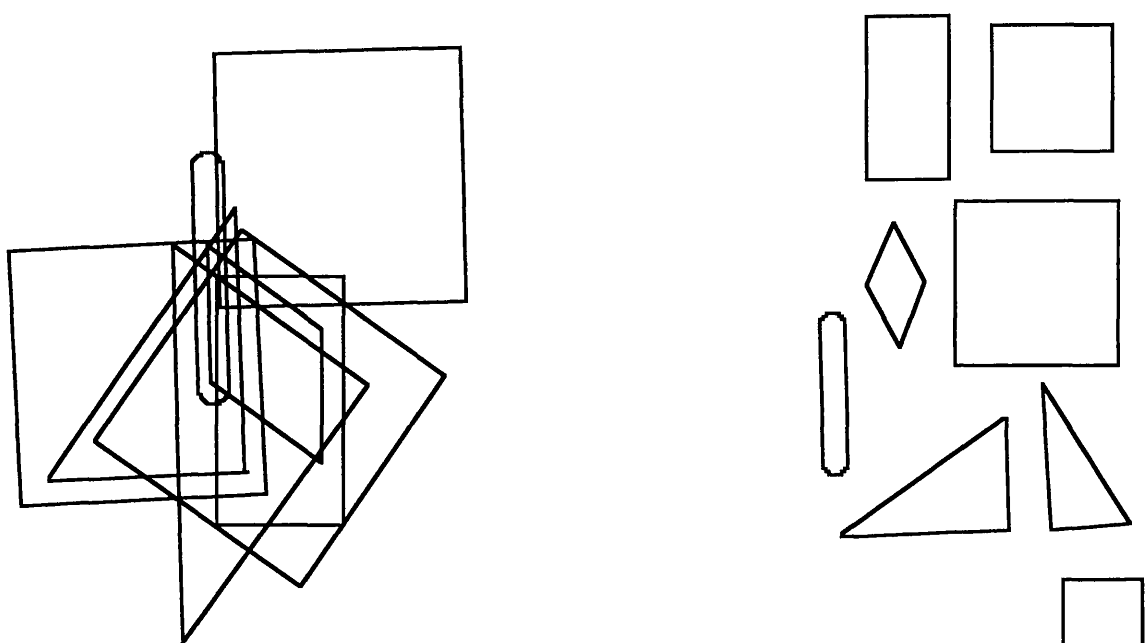
| 10 |  |

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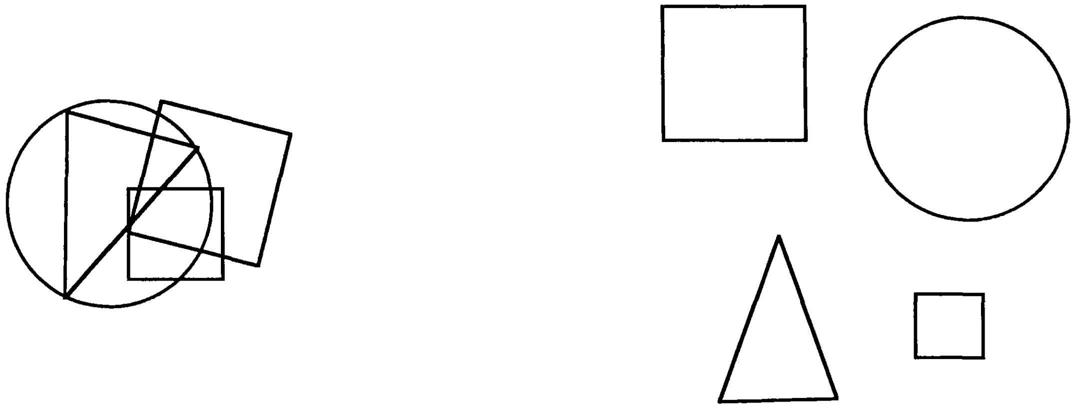
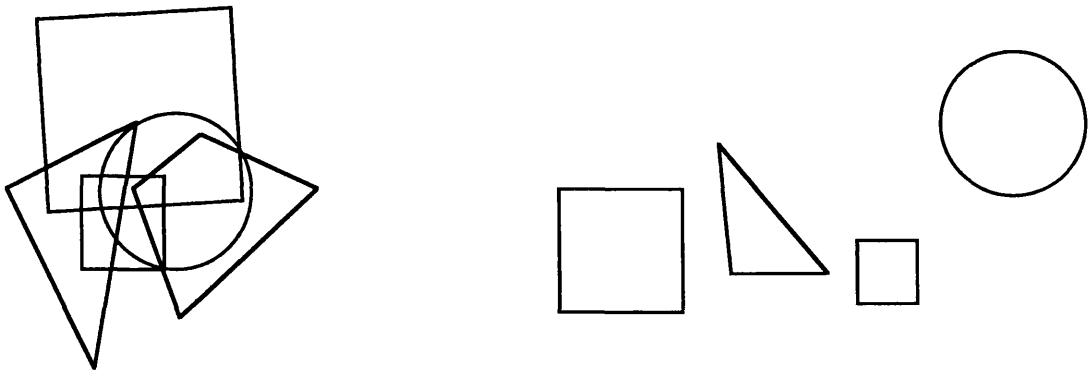
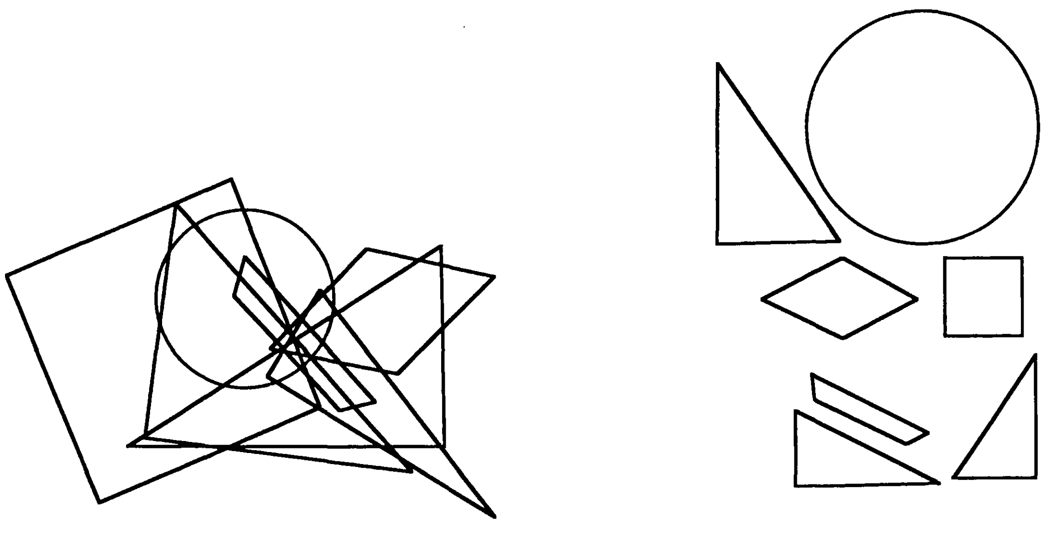
| 11 |  |
| 12 |  |
| 13 |  |
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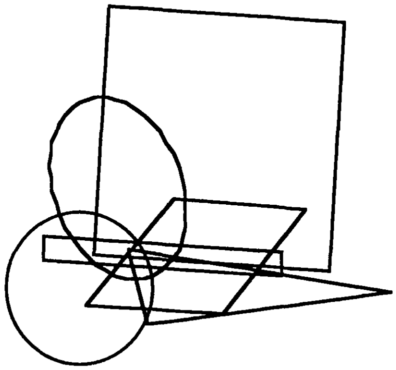
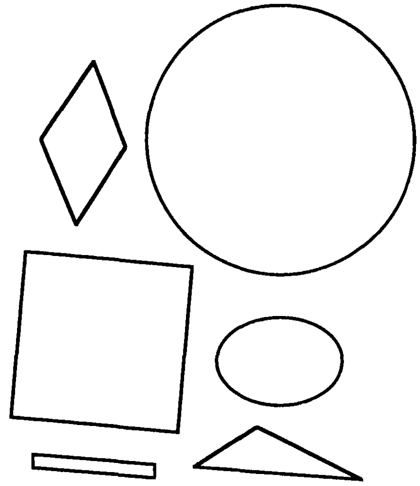
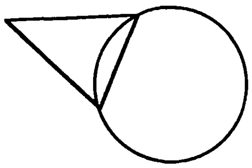
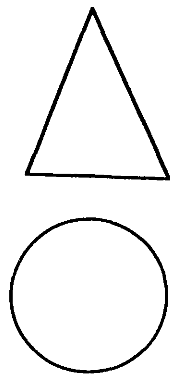
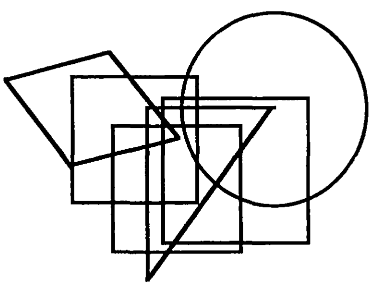
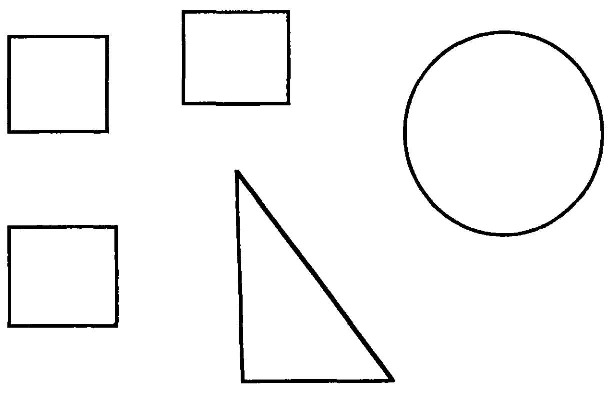
| 15 |  |  |
| 16 |  |  |
| 17 |  |  |

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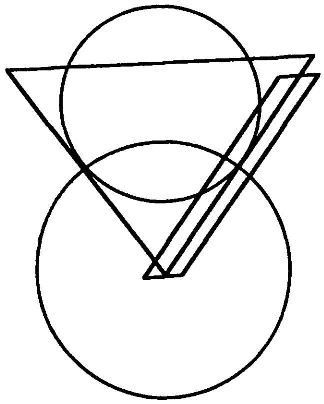
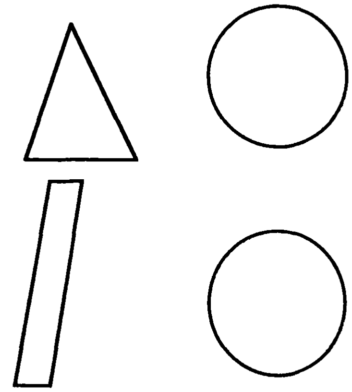
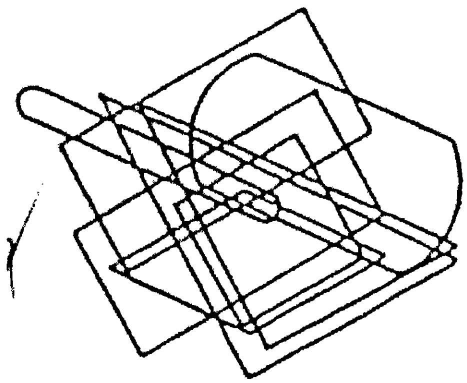
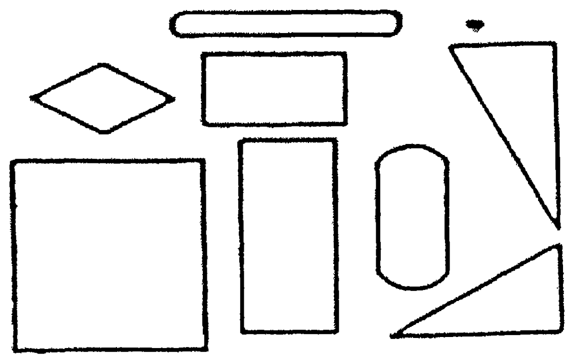
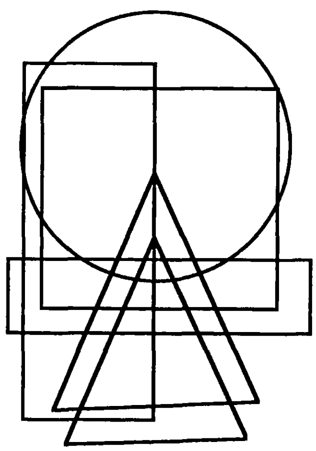
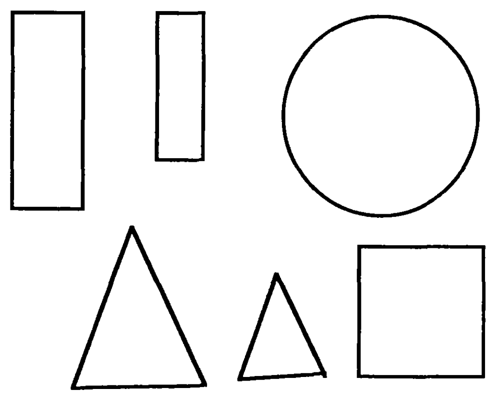
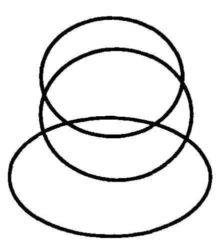
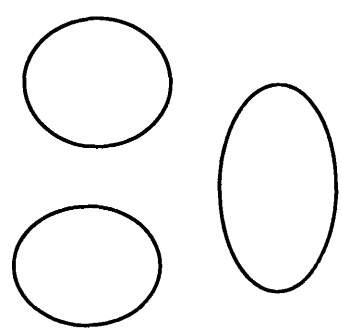
| 18 |  |  |
| 19 |  |  |
| 20 |  |  |
| 21 |  |  |

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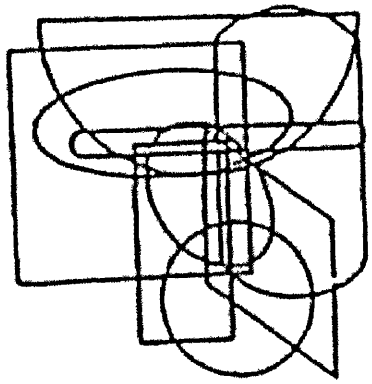
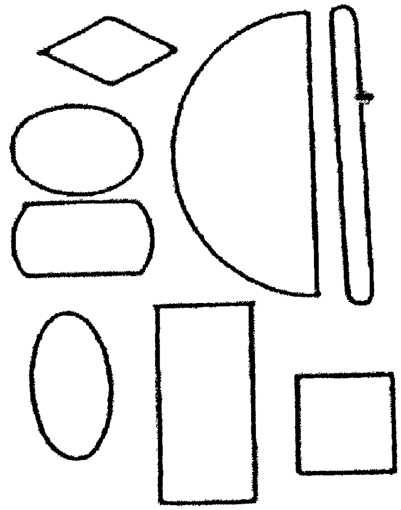
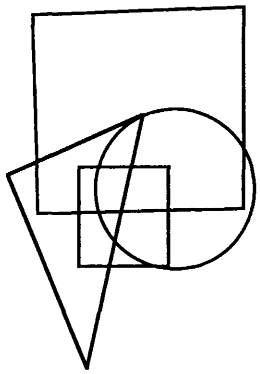
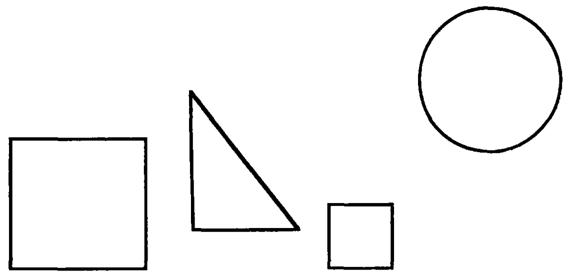
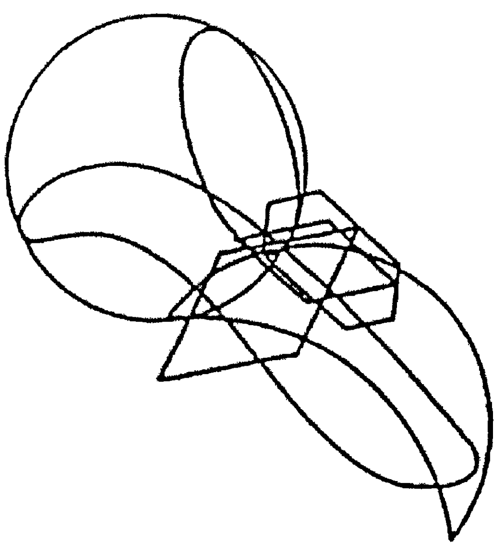
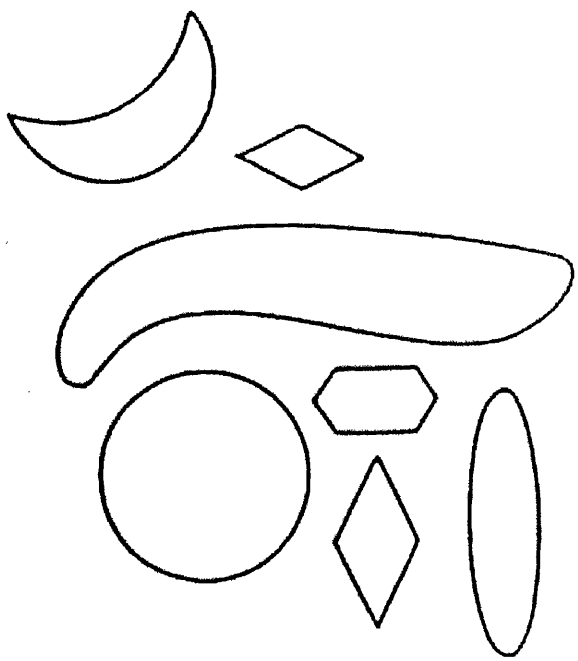
| 22 |  |  |
| 23 |  |  |
| 24 |  |  |

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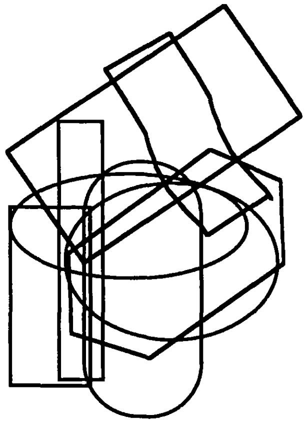
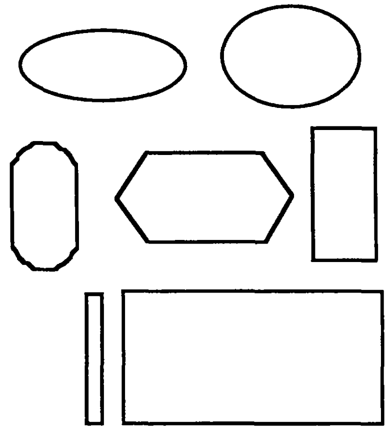
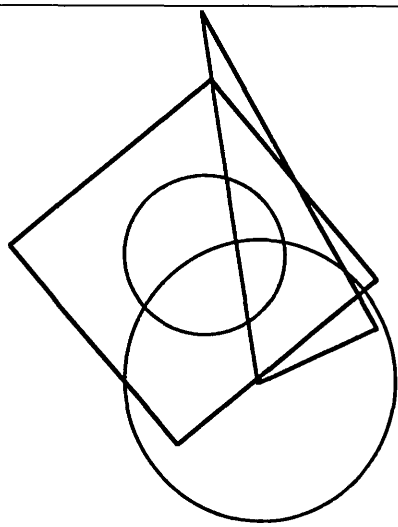
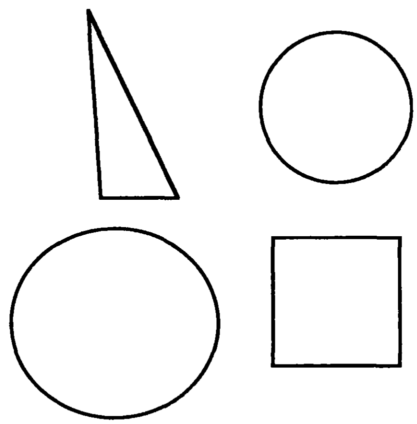
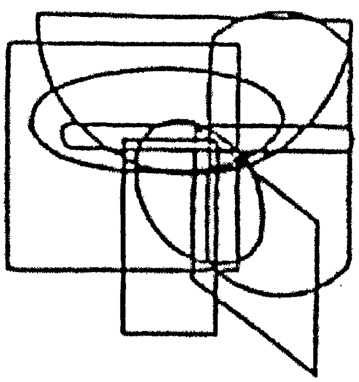
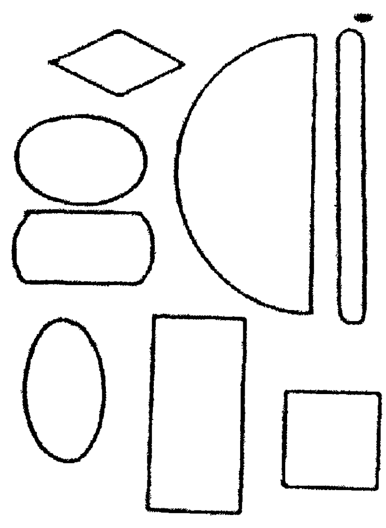
| 25 |  |  |
| 26 |  |  |
| 27 |  |  |

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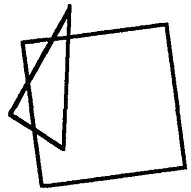
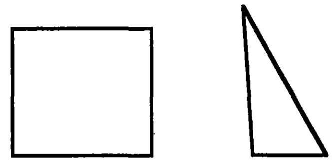
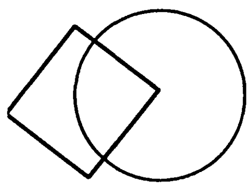
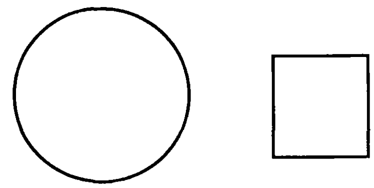
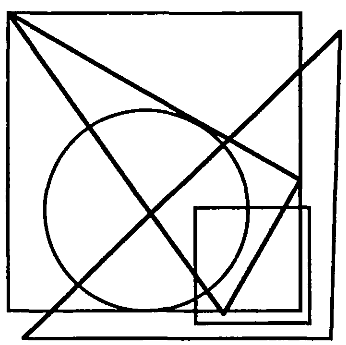
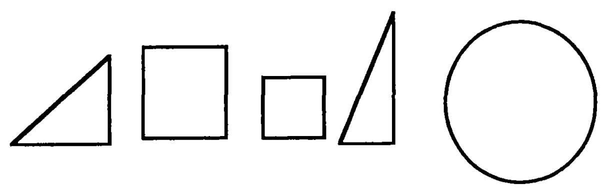
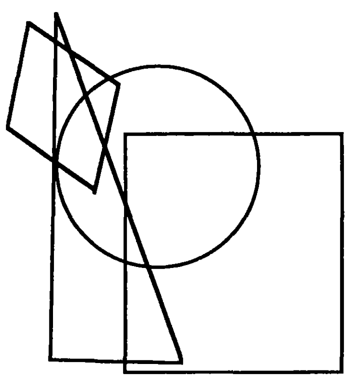
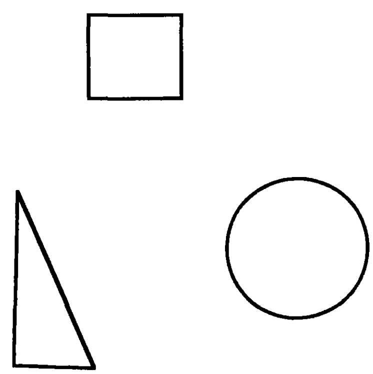
| 28 |  |  |
| 29 |  |  |
| 30 |  |  |
| 31 |  |  |

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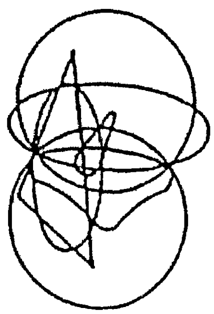
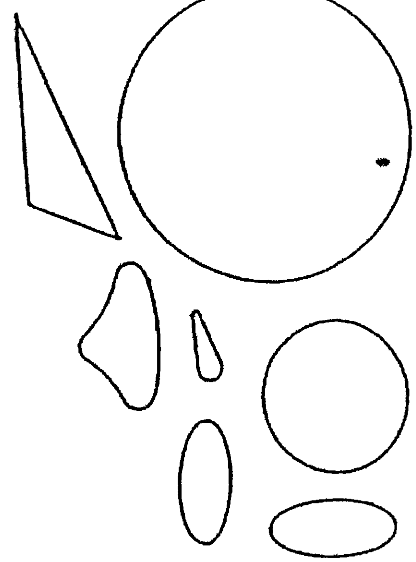
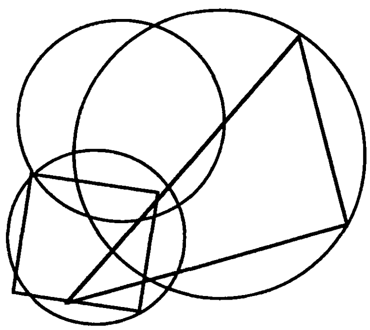
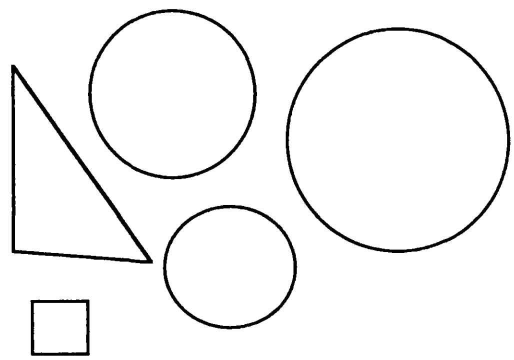
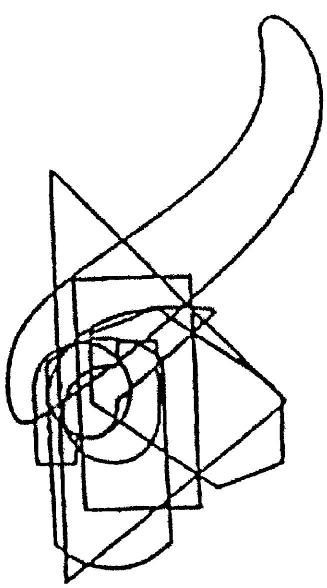
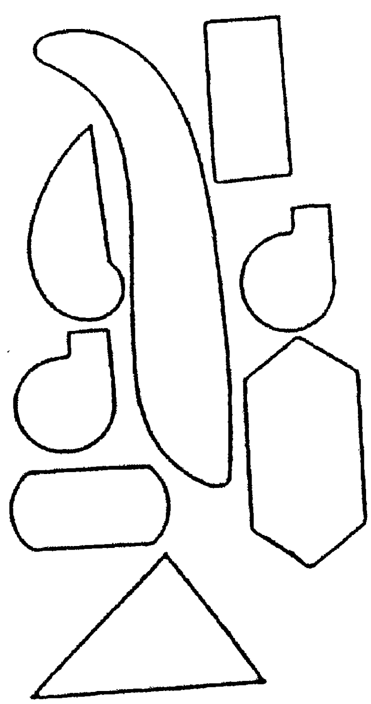
| 32 |  |  |
| 33 |  |  |
| 34 |  |  |

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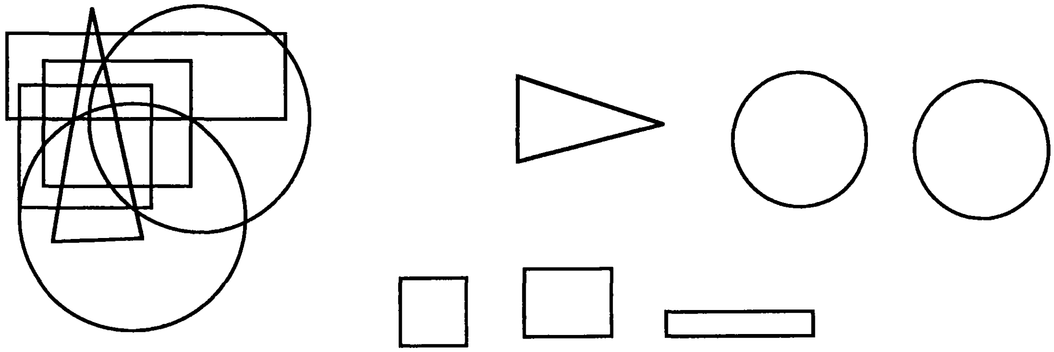
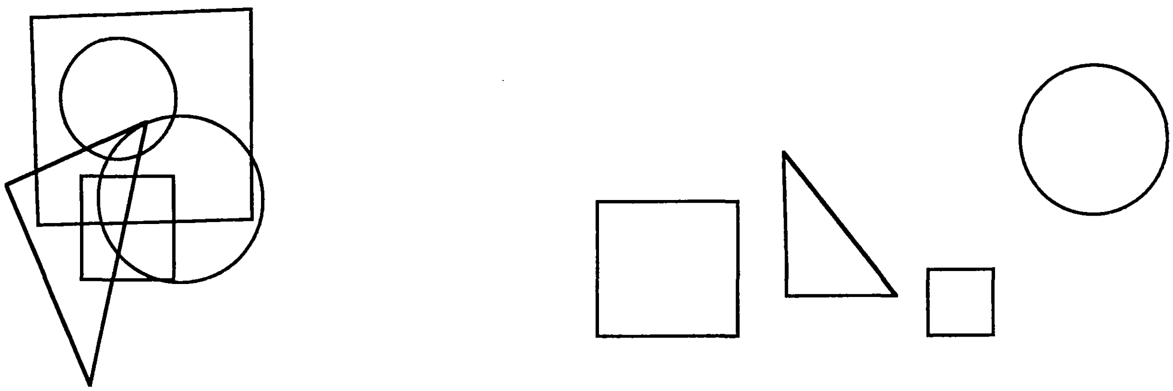
| 35 |  |
| 36 |  |

# Appendix B

## Attitude Questionnaire

# WHAT ARE YOUR OPINIONS ?

**This is NOT a test**

**Please give your honest opinions**

1. Your registration number: ....................................................

This is an example. If you had to describe "a racing car" you could do it like this:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| quick | ☑ | ☐ | ☐ | ☐ | ☐ | ☐ | slow |
| important | ☐ | ☐ | ☑ | ☐ | ☐ | ☐ | unimportant |
| safe | ☐ | ☐ | ☐ | ☐ | ☑ | ☐ | dangerous |

**The positions of the ticks between the word pairs show that you consider it as very quick, slightly more important than unimportant and quite dangerous.**

*Use the same method to answer the question 2 and 3.*

2. Think about your studies in science.
*Tick **one** box on each line.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| I enjoy my studies | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | I do not enjoy my studies |
| I find science difficult | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | I find science easy |
| Science is useful | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | Science is not useful |
| Science is boring | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | Science is interesting |
| Science topics are irrelevant to me | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | Science topics are relevant to me |
| There is too much work | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | There is not enough work |
| Laboratory work is good fun | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | Laboratory work is not good fun |
| I learn nothing from laboratory work | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | I learn a lot from laboratory work |
| My textbooks are helpful | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | My text books are not helpful |

3. In your opinion, A scientist is:
*Tick **one** box on each line.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| responsible | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | irresponsible |
| clever | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | dull |
| rich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | poor |
| valuable to society | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | worthless to society |
| popular | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | not popular |
| involved with people | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | detached from people |
| a hard worker | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | not a hard worker |
| doing a dangerous job | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | doing a safe job |

4. Below you will find several statements.
*Read each carefully, and decide whether you agree or disagree with it.*
*Tick **one** box on each line.*

| | Strongly agree | Agree | Neutral | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| I am coping with my science work very well | ☐ | ☐ | ☐ | ☐ | ☐ |
| Science is an important subject for my life | ☐ | ☐ | ☐ | ☐ | ☐ |
| I am getting better at science | ☐ | ☐ | ☐ | ☐ | ☐ |
| My understanding about the natural world is progressing by virtue of studying science | ☐ | ☐ | ☐ | ☐ | ☐ |
| I think current school science is enough to meet my curiosity about the natural world | ☐ | ☐ | ☐ | ☐ | ☐ |
| I am enjoying studying science | ☐ | ☐ | ☐ | ☐ | ☐ |

5. Look at the following aspects of learning science.
*Tick **one** box on each line to shown how each has helped you to understand science.*

| | *All the time* | *Quite a lot* | *A little* | *Not at all* |
|---|---|---|---|---|
| Terminology | ☐ | ☐ | ☐ | ☐ |
| Scientific concept | ☐ | ☐ | ☐ | ☐ |
| Applying scientific knowledge to everyday problem | ☐ | ☐ | ☐ | ☐ |
| Mathematical calculation | ☐ | ☐ | ☐ | ☐ |
| Science laboratory | ☐ | ☐ | ☐ | ☐ |
| Graphs | ☐ | ☐ | ☐ | ☐ |
| Diagrams | ☐ | ☐ | ☐ | ☐ |
| Scientific apparatus | ☐ | ☐ | ☐ | ☐ |

6. Why do you study science? Here are some reasons.
*Tick as **many** as you wish.*

- ☐ I really enjoy studying science
- ☐ I like my science teacher
- ☐ I need to study science to go to university
- ☐ Science is useful in my life
- ☐ Science is easy to gain good grades
- ☐ I want to get a job relevant to science
- ☐ My parents persuade me to study science
- ☐ Any other reasons
(please write here: ................................................)

7. What would you like to be when you are grown up?
*Choose the **THREE** jobs which most interest you,*

| | | |
|---|---|---|
| A. scientist | B. lawyer | C. doctor |
| D. sports player | E. artist | F. musician |
| G. politician | H. announcer | I. businessman |
| J. hairdresser | K. engineer | L. any others (please write here: .........................................) |

First: .......................... Second: .......................... Third: ..........................

8. Are you interested in science?
☐ Yes ☐ No
*If your answer is yes, ignore question 9 and go to question 10.*
*If your answer is no, please answer the question 9.*

9. Which factor(s) caused you to lose interest in science?
*Tick as **many** as you wish*

- ☐ science lessons
- ☐ calculation
- ☐ too much work load
- ☐ science laboratory
- ☐ bad grades
- ☐ school environment
- ☐ too difficult content
- ☐ no need for my life
- ☐ any other reasons
(please write here: ........................)

10. How have you **usually** studied science so far?
*Tick **ONE** box.*

- ☐ I have tried to memorise science knowledge such as concepts, rules, theory as much as I can
- ☐ I have tried to understand science knowledge such as concepts, rules, theory as much as I can

11. Who (or which) do you usually rely on when you have difficulty in studying science?
*Tick as **many** as you wish.*

- ☐ school textbook
- ☐ school teacher
- ☐ friends
- ☐ self-teaching manual
- ☐ out-of-school teacher
- ☐ any others (please write here: .........................................................................)
- ☐ general science book
- ☐ family member

12. Which of the following topics interest you?
*Tick as **many** as you wish.*

- ☐ How the light refracts when it goes through a lens?
- ☐ How a rainbow is made?
- ☐ What condition makes the press and volume of gas change?
- ☐ How do we classify rocks?
- ☐ Why is an air balloon lifted when it is heated?
- ☐ How can we observe a cell with a microscope?
- ☐ What is the difference between a vegetable cell and an animal cell?
- ☐ How does the destruction of ozone layer affect human life?

13. Which type of lesson or activity do you like?
*Pick the **THREE** things you like most.*

| | | |
|---|---|---|
| A. Listening to lecture | B. Discussion | C. Solving exercises and problems |
| D. Individual task | E. Watching science video tape | E. Making equipment or model |
| F. Group task | G. Laboratory | H. any others (please write here: .........) |

First: .......................... Second: .......................... Third: ..........................

# Appendix C

## Statistical Results and Tables of the study

## Correlations between WMS and attitudes towards studies in science

| Correlations between WMS and attitudes towards studies in science | | Level 1 | Level 3 |
|---|---|---|---|
| I do not enjoy my studies | Correlation Coefficient | -.138** | -.139** |
| | Sig. (2-tailed) | .001 | .001 |
| | N | 362 | 349 |
| I find science easy | Correlation Coefficient | .138** | .102* |
| | Sig. (2-tailed) | .001 | .014 |
| | N | 363 | 349 |
| Science is not useful | Correlation Coefficient | -.109** | -.031 |
| | Sig. (2-tailed) | .008 | .454 |
| | N | 364 | 348 |
| Science is interesting | Correlation Coefficient | .126** | .118** |
| | Sig. (2-tailed) | .002 | .004 |
| | N | 363 | 350 |
| Science topics are relevant to me | Correlation Coefficient | .069 | .073 |
| | Sig. (2-tailed) | .086 | .075 |
| | N | 361 | 349 |
| There is not enough work | Correlation Coefficient | .039 | .076 |
| | Sig. (2-tailed) | .331 | .063 |
| | N | 363 | 347 |
| Laboratory work is not good fun | Correlation Coefficient | -.049 | -.067 |
| | Sig. (2-tailed) | .239 | .103 |
| | N | 362 | 349 |
| I learn a lot from laboratory work | Correlation Coefficient | .029 | .051 |
| | Sig. (2-tailed) | .475 | .216 |
| | N | 361 | 349 |
| My text books are not helpful | Correlation Coefficient | -.022 | .050 |
| | Sig. (2-tailed) | .585 | .220 |
| | N | 363 | 347 |

*. correlation is significant at the 0.05 level (2-tailed)

**. correlation is significant at the 0.01 level (2-tailed)

## Students' attitudes toward studies in science

| | | | | | | | | $X^2$ | Probability | df |
|---|---|---|---|---|---|---|---|---|---|---|
| I enjoy my studies | 14 | 16 | 26 | 20 | 12 | 11 | I do not enjoy my studies | 64.06 | <0.001 | 5 |
| | 7 | 15 | 18 | 20 | 21 | 19 | | | | |
| I find science difficult | 17 | 22 | 24 | 18 | 13 | 7 | I find science easy | 22.54 | <0.001 | 4 |
| | 22 | 27 | 24 | 17 | 8 | 3 | | | | |
| Science is useful | 32 | 24 | 28 | 13 | 1 | 2 | Science is not useful | 6.80 | n.s | 3 |
| | 26 | 27 | 28 | 10 | 5 | 3 | | | | |
| Science is boring | 12 | 14 | 18 | 29 | 14 | 14 | Science is interesting | 13.36 | <0.05 | 5 |
| | 15 | 15 | 20 | 27 | 14 | 9 | | | | |
| Science topics are irrelevant | 4 | 8 | 17 | 27 | 19 | 25 | Science topics are | 54.97 | <0.001 | 4 |
| to me | 10 | 11 | 20 | 28 | 20 | 11 | relevant to me | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| There is too much work | 12 | 10 | 25 | 24 | 17 | 12 | There is not enough work | 19.74 | <0.01 | 5 |
| | 13 | 16 | 24 | 25 | 12 | 8 | | | | |
| Laboratory work is good fun | 50 | 23 | 13 | 5 | 3 | 6 | Laboratory work is not good fun | 62.16 | <0.001 | 4 |
| | 31 | 25 | 18 | 9 | 9 | 7 | | | | |
| I learn nothing from laboratory work | 3 | 5 | 11 | 22 | 28 | 31 | I learn a lot from laboratory work | 95.41 | <0.001 | 4 |
| | 9 | 9 | 17 | 27 | 25 | 14 | | | | |
| My textbooks are helpful | 19 | 19 | 25 | 16 | 12 | 9 | My text books are not helpful | 39.91 | <0.001 | 5 |
| | 9 | 13 | 27 | 22 | 14 | 14 | | | | |
| Level 1(N=364) | | | | | | | Level 3 (N=350) | | | |

"df" is "degrees of freedom"

"ns" means "not significant"

## Correlations between WMS and attitudes towards scientist

| Correlations between WMS and attitudes towards scientist | | Level 1 | Level 3 |
|---|---|---|---|
| irresponsible | Correlation Coefficient | -.028 | .021 |
| | Sig. (2-tailed) | .495 | .610 |
| | N | 362 | 350 |
| dull | Correlation Coefficient | .041 | -.039 |
| | Sig. (2-tailed) | .334 | .368 |
| | N | 363 | 349 |
| poor | Correlation Coefficient | .005 | -.105* |
| | Sig. (2-tailed) | .905 | .011 |
| | N | 360 | 348 |
| worthless to society | Correlation Coefficient | .020 | -.084* |
| | Sig. (2-tailed) | .633 | .049 |
| | N | 363 | 348 |
| not popular | Correlation Coefficient | .076 | .032 |
| | Sig. (2-tailed) | .060 | .440 |
| | N | 363 | 349 |
| detached from people | Correlation Coefficient | .006 | .051 |
| | Sig. (2-tailed) | .876 | .209 |
| | N | 362 | 349 |
| not a hard worker | Correlation Coefficient | .024 | -.048 |
| | Sig. (2-tailed) | .554 | .255 |
| | N | 363 | 349 |
| doing a safe job | Correlation Coefficient | .060 | .072 |
| | Sig. (2-tailed) | .138 | .086 |
| | N | 362 | 348 |

*. correlation is significant at the 0.05 level (2-tailed)

**. correlation is significant at the 0.01 level (2-tailed)

## Students' attitudes toward scientists

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| responsible | 30 | 20 | 33 | 11 | 3 | 3 | irresponsible |
| | 22 | 20 | 27 | 16 | 10 | 5 | |
| clever | 54 | 22 | 16 | 4 | 1 | 3 | dull |
| | 46 | 32 | 14 | 5 | 1 | 2 | |
| rich | 11 | 7 | 29 | 25 | 12 | 16 | poor |
| | 10 | 11 | 32 | 23 | 14 | 10 | |
| valuable to society | 48 | 29 | 13 | 7 | 1 | 2 | worthless to society |
| | 47 | 31 | 15 | 4 | 3 | 1 | |
| popular | 7 | 7 | 23 | 34 | 13 | 16 | not popular |
| | 4 | 7 | 23 | 31 | 21 | 15 | . |
| involved with people | 26 | 24 | 22 | 14 | 6 | 9 | detached from people |
| | 17 | 24 | 20 | 15 | 14 | 9 | |
| a hard worker | 41 | 27 | 21 | 7 | 2 | 4 | not a hard worker |
| | 32 | 34 | 23 | 8 | 2 | 1 | |
| doing a dangerous job | 7 | 4 | 11 | 23 | 25 | 31 | doing a safe job |
| | 3 | 4 | 10 | 26 | 33 | 24 | |

"df" is "degrees of freedom"

"ns" means "not significant"

## Correlations between WMS and self-perception in studying science

| Correlations between WMS and self-perception in studying science | | Level 1 | Level 3 |
|---|---|---|---|
| I am coping with my science work very well | Correlation | - | -.079 |
| | Sig. (2-tailed) | .001 | .061 |
| | N | 364 | 350 |
| Science is an important subject for my life | Correlation | - | - |
| | Sig. (2-tailed) | .000 | .002 |
| | N | 364 | 350 |
| I am getting better at science | Correlation | - | -.101* |
| | Sig. (2-tailed) | .001 | .016 |
| | N | 362 | 350 |
| My understanding about the natural world is progressing by virtue of studying science | Correlation | - | -.107* |
| | Sig. (2-tailed) | .010 | .011 |
| | N | 361 | 347 |
| I think current school science is enough to meet my curiosity about the natural world | Correlation | -.092* | -.080 |
| | Sig. (2-tailed) | .023 | .055 |
| | N | 362 | 347 |
| I am enjoying studying science | Correlation | - | - |
| | Sig. (2-tailed) | .000 | .000 |
| | N | 362 | 350 |

*. correlation is significant at the 0.05 level (2-tailed)

**. correlation is significant at the 0.01 level (2-tailed)

## Students' self-perception about studying science

| | Strongly agree | Agree | Neutral | Disagree | Strongly disagree | $X^2$ | probability | df |
|---|---|---|---|---|---|---|---|---|
| I am coping with my science work very well | 6 | 20 | 53 | 15 | 6 | 23.43 | <0.001 | 3 |
| | 4 | 17 | 47 | 22 | 9 | | | |
| Science is an important subject for my life | 11 | 23 | 41 | 18 | 7 | 76.57 | <0.001 | 4 |
| | 6 | 18 | 32 | 34 | 11 | | | |
| I am getting better at science | 9 | 32 | 35 | 17 | 6 | 45.60 | <0.001 | 4 |
| | 6 | 21 | 37 | 25 | 10 | | | |
| My understanding about the natural world is progressing by virtue of studying science | 12 | 26 | 39 | 17 | 6 | 17.73 | <0.01 | 4 |
| | 7 | 28 | 33 | 23 | 8 | | | |
| I think current school science is enough to meet my curiosity about the natural world | 15 | 28 | 30 | 19 | 8 | 23.74 | <0.001 | 4 |
| | 8 | 28 | 27 | 26 | 10 | | | |
| I am enjoying studying science | 10 | 25 | 33 | 19 | 13 | 43.40 | <0.001 | 4 |
| | 5 | 16 | 33 | 26 | 19 | | | |

*. correlation is significant at the 0.05 level (2-tailed) **. correlation is significant at the 0.01 level (2-tailed)

## Correlations between WMS and views about various aspects of learning science

| Correlations between WMS and views about various aspects of learning science | | Level 1 | Level 3 |
|---|---|---|---|
| Terminology | Correlation Coefficient | -.024 | -.014 |
| | Sig. (2-tailed) | .573 | .753 |
| | N | 359 | 347 |
| Scientific concept | Correlation Coefficient | -.138** | -.106* |
| | Sig. (2-tailed) | .001 | .015 |
| | N | 358 | 347 |
| Applying scientific knowledge to everyday problem | Correlation Coefficient | -.160** | -.069 |
| | Sig. (2-tailed) | .000 | .108 |
| | N | 354 | 345 |
| Mathematical calculation | Correlation Coefficient | -.061 | -.043 |
| | Sig. (2-tailed) | .149 | .318 |
| | N | 354 | 346 |
| Science laboratory | Correlation Coefficient | -.056 | -.107* |
| | Sig. (2-tailed) | .187 | .012 |
| | N | 356 | 346 |
| Graphs | Correlation Coefficient | -.055 | -.075 |
| | Sig. (2-tailed) | .192 | .085 |
| | N | 355 | 346 |
| Diagrams | Correlation Coefficient | -.015 | -.105* |
| | Sig. (2-tailed) | .726 | .016 |
| | N | 356 | 346 |
| Scientific apparatus | Correlation Coefficient | -.048 | -.119** |
| | Sig. (2-tailed) | .260 | .006 |
| | N | 353 | 341 |

*. correlation is significant at the 0.05 level (2-tailed)

**. correlation is significant at the 0.01 level (2-tailed)

## Students' views about helpfulness of various factors in learning science

| | All the time | Quite a lot | A little | Not at all |
|---|---|---|---|---|
| Terminology | 10 | 43 | 41 | 6 |
| | 4 | 35 | 49 | 12 |
| Scientific concept | 15 | 42 | 37 | 6 |
| | 6 | 44 | 41 | 9 |
| Applying scientific knowledge to everyday problem | 17 | 39 | 36 | 8 |
| | 13 | 36 | 40 | 12 |
| Mathematical calculation | 10 | 25 | 43 | 22 |
| | 8 | 32 | 43 | 17 |
| Science laboratory | 31 | 41 | 23 | 5 |
| | 12 | 36 | 36 | 16 |
| Graphs | 10 | 30 | 46 | 15 |
| | 5 | 27 | 51 | 17 |
| Diagrams | 9 | 25 | 48 | 18 |
| | 4 | 25 | 51 | 20 |
| Scientific apparatus | 29 | 40 | 26 | 6 |
| | 9 | 43 | 36 | 11 |

*. correlation is significant at the 0.05 level (2-tailed)

**. correlation is significant at the 0.01 level (2-tailed)

## The Reasons that Students Study Science (Level 1)

| | Level 1 (%) | | | |
|---|---|---|---|---|
| | All (N=364) | High (N=100) | Mid (N=166) | Low (N=98) |
| I really enjoy studying science | 25 | 32 | 25 | 16 |
| Science is easy to gain good grades | 11 | 8 | 11 | 12 |
| I like my science teacher | 14 | 12 | 16 | 11 |
| I want to get a job relevant to science | 18 | 26 | 15 | 16 |
| I need to study science to go to university | 53 | 46 | 52 | 59 |
| My parents persuade me to study science | 18 | 20 | 17 | 19 |
| Science is useful in my life | 39 | 49 | 41 | 24 |

## The Reasons that Students Study Science (Level 3)

| | Level 3 (%) | | | |
|---|---|---|---|---|
| | All (N=350) | High (N=95) | Mid (N=172) | Low (N=83) |
| I really enjoy studying science | 17 | 15 | 17 | 13 |
| Science is easy to gain good grades | 11 | 9 | 14 | 6 |
| I like my science teacher | 10 | 7 | 11 | 9 |
| I want to get a job relevant to science | 13 | 21 | 11 | 9 |
| I need to study science to go to university | 57 | 66 | 59 | 44 |
| My parents persuade me to study science | 12 | 9 | 12 | 12 |
| Science is useful in my life | 30 | 37 | 27 | 26 |

## Students' Job Desire

| | (1) First (%) | | (2) Second (%) | | (3) Third (%) | | (1)+(2)+(3) | |
|---|---|---|---|---|---|---|---|---|
| | Level 1 | **Level 3** | Level 1 | **Level 3** | Level 1 | **Level 3** | Level 1 | **Level 3** |
| Scientist | 9 | **5** | 7 | **6** | 4 | **4** | 20 | **15** |
| lawyer | 8 | **9** | 15 | **9** | 10 | **11** | 33 | **29** |
| doctor | 20 | **12** | 16 | **14** | 14 | **11** | 50 | **37** |
| sports player | 6 | **3** | 4 | **4** | 6 | **6** | 16 | **13** |
| artist | 2 | **1** | 3 | **4** | 5 | **3** | 10 | **8** |
| musician | 4 | **6** | 7 | **9** | 4 | **5** | 15 | **20** |
| politician | 2 | **1** | 3 | **3** | 2 | **5** | 7 | **9** |
| announcer | 4 | **5** | 5 | **10** | 10 | **7** | 19 | **22** |
| businessman | 7 | **12** | 12 | **19** | 17 | **18** | 36 | **49** |
| hairdresser | 1 | **3** | 7 | **5** | 4 | **5** | 12 | **13** |
| engineer | 2 | **1** | 5 | **5** | 5 | **8** | 12 | **14** |
| teacher | 10 | **13** | 4 | **3** | 4 | **4** | 18 | **20** |

## Level 1 students' job desire against high, middle and low working memory space

| | (1) First Choice(%) | | | (2) Second Choice(%) | | | (3) Third Choice(%) | | | (1)+(2)+(3) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Mid | Low | High | Mid | Low | High | Mid | Low | High | Mid | Low |
| Scientist | 17 | 8 | 4 | 11 | 7 | 3 | 3 | 6 | 1 | 31 | 21 | 8 |
| lawyer | 8 | 6 | 11 | 15 | 15 | 13 | 7 | 10 | 12 | 30 | 31 | 36 |
| doctor | 20 | 18 | 22 | 15 | 18 | 14 | 11 | 15 | 14 | 46 | 51 | 50 |
| sports player | 8 | 4 | 7 | 4 | 2 | 6 | 4 | 6 | 8 | 16 | 12 | 21 |
| artist | 1 | 2 | 1 | 5 | 2 | 3 | 5 | 6 | 3 | 11 | 10 | 7 |
| musician | 4 | 5 | 4 | 5 | 7 | 9 | 4 | 4 | 4 | 13 | 16 | 17 |
| politician | 0 | 2 | 2 | 5 | 2 | 3 | 1 | 1 | 3 | 6 | 7 | 8 |
| announcer | 2 | 5 | 5 | 1 | 7 | 7 | 9 | 3 | 6 | 12 | 18 | 18 |
| businessman | 9 | 7 | 5 | 10 | 14 | 10 | 19 | 17 | 18 | 38 | 38 | 33 |
| hairdresser | 1 | 1 | 1 | 5 | 7 | 9 | 2 | 5 | 5 | 8 | 13 | 15 |
| engineer | 0 | 2 | 2 | 5 | 5 | 5 | 11 | 3 | 2 | 16 | 10 | 9 |
| teacher | 5 | 14 | 9 | 2 | 4 | 4 | 3 | 4 | 5 | 10 | 22 | 18 |

## Level 3 students' job desire against high, middle and low working memory space

| | (1) First Choice(%) | | | (2) Second Choice(%) | | | (3) Third Choice(%) | | | (1)+(2)+(3) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Mid | Low | High | Mid | Low | High | Mid | Low | High | Mid | Low |
| Scientist | 8 | 4 | 2 | 10 | 5 | 4 | 2 | 5 | 6 | 20 | 14 | 12 |
| lawyer | 7 | 10 | 8 | 7 | 11 | 10 | 17 | 11 | 5 | 31 | 32 | 23 |
| doctor | 19 | 10 | 10 | 14 | 13 | 16 | 11 | 13 | 10 | 44 | 36 | 36 |
| sports player | 3 | 4 | 4 | 3 | 6 | 2 | 3 | 4 | 15 | 9 | 14 | 21 |
| artist | 1 | 1 | 4 | 5 | 4 | 2 | 0 | 5 | 0 | 6 | 10 | 6 |
| musician | 5 | 5 | 8 | 5 | 11 | 10 | 0 | 8 | 6 | 10 | 24 | 24 |
| politician | 0 | 1 | 2 | 4 | 2 | 6 | 8 | 4 | 5 | 12 | 7 | 13 |
| announcer | 4 | 6 | 2 | 10 | 14 | 4 | 8 | 4 | 10 | 22 | 24 | 16 |
| businessman | 8 | 14 | 13 | 24 | 17 | 19 | 17 | 19 | 17 | 49 | 50 | 49 |
| hairdresser | 0 | 4 | 5 | 1 | 8 | 2 | 8 | 2 | 7 | 9 | 14 | 14 |
| engineer | 1 | 2 | 0 | 5 | 3 | 7 | 10 | 11 | 1 | 16 | 16 | 8 |
| teacher | 13 | 14 | 12 | 3 | 2 | 5 | 8 | 3 | 0 | 24 | 19 | 17 |

## Factors Causing Students to Lose Interest in Science (Level 1)

| | Level 1 (%) | | | |
|---|---|---|---|---|
| | All (N=158) | High (N=33) | Mid (N=70) | Low (N=51) |
| Science lessons | 20 | 12 | 23 | 20 |
| Science laboratory | 6 | 6 | 7 | 2 |
| Too difficult content | 77 | 73 | 79 | 77 |
| Calculation | 14 | 12 | 14 | 14 |
| Bad grades | 61 | 52 | 61 | 67 |
| No need for my life | 16 | 9 | 17 | 18 |
| Too much work load | 20 | 24 | 21 | 14 |
| School environment | 5 | 12 | 1 | 6 |

* This item was only given to the students who said they were not interested in science.

## Factors Causing Students to Lose Interest in Science (Level 3)

| | Level 3 (%) | | | |
|---|---|---|---|---|
| | All (N=226) | High (N=50) | Mid (N=111) | Low (N=65) |
| Science lessons | 40 | 40 | 41 | 39 |
| Science laboratory | 12 | 16 | 7 | 17 |
| Too difficult content | 77 | 82 | 80 | 71 |
| Calculation | 35 | 32 | 37 | 32 |
| Bad grades | 55 | 52 | 56 | 55 |
| No need for my life | 20 | 18 | 21 | 19 |
| Too much work load | 16 | 16 | 14 | 17 |
| School environment | 10 | 10 | 9 | 12 |

* This item was only given to the students who said they were not interested in science.

## Students' Interest in Science

| Are you interested in science? | Level 1 (%) | | | | Level 3 (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | All (N=364) | High (N=100) | Mid (N=166) | Low (N=98) | All (N=350) | High (N=95) | Mid (N=172) | Low (N=83) |
| Yes | 54 | 66 | 55 | 39 | | 48 | 36 | 22 |
| No | 44 | 33 | 42 | 57 | | 53 | 64 | 78 |

## Chi- Square Values between High and Low Working Memory Capacity Students

| Are you interested in science? | $\chi^2$ | probability | df | Favoured |
|---|---|---|---|---|
| Level 1 (high-low) | 13.4 | <0.001 | 1 | high |
| Level 3 (high-low) | 8.4 | <0.01 | 1 | high |

## Students' Way of Learning Science

| | | I have tried to understand science knowledge such as concepts, rules, theory as much as I can | I have tried to memorize science knowledge such as concepts, rules, theory as much as I can |
|---|---|---|---|
| Level 1 | All (N=364) | 59% | 33 % |
| | High (N=100) | 71% | 24 % |
| | Mid (N=166) | 58 % | 34 % |
| | Low (N=98) | 50 % | 39 % |
| Level 3 | All (N=350) | 57 % | 33% |
| | High (N=85) | 70 % | 25% |
| | Mid (N=172) | 61 % | 31% |
| | Low (N=78) | 37 % | 45 % |

## Chi- Square Values between High, Middle and Low Working Memory Capacity Students

| The way of learning | $\chi^2$ | probability | df |
|---|---|---|---|
| Level 1(high-low) | 6.9 | <0.01 | 1 |
| Level 3(high-low) | 12.0 | <0.001 | 1 |

## The object that student usually rely on when they have difficulty in studying science (Level 1)

| | Level 1 (%) | | | |
|---|---|---|---|---|
| | All (N=364) | High (N=100) | Mid (N=166) | Low (N=98) |
| School textbook | 32 | 31 | 36 | 26 |
| Self-teaching manual | 46 | 40 | 51 | 46 |
| General science book | 17 | 24 | 16 | 10 |
| School teacher | 29 | 31 | 30 | 26 |
| Out-of-school teacher | 48 | 43 | 50 | 49 |
| Family member | 23 | 28 | 24 | 18 |
| Friends | 36 | 39 | 38 | 31 |

## The object that student usually rely on when they have difficulty in studying science (Level 3)

| | Level 3 | | | |
|---|---|---|---|---|
| | All (N=350) | High (N=85) | Mid (N=172) | Low (N=78) |
| School textbook | 26 | 18 | 30 | 27 |
| Self-teaching manual | 48 | 53 | 48 | 41 |
| General science book | 17 | 17 | 17 | 16 |
| School teacher | 18 | 21 | 16 | 16 |
| Out-of-school teacher | 52 | 52 | 54 | 48 |
| Family member | 10 | 13 | 9 | 10 |
| Friends | 43 | 42 | 44 | 40 |

## Topics that interest students (Level 1)

| Which of the following topics interest you? | All (%) (N=364) | High (%) (N=100) | Mid (%) (N=166) | Low(%) (N=98) |
|---|---|---|---|---|
| How the light refracts when it goes through a lens? | 17 | 19 | 18 | 13 |
| How a rainbow is made? | 34 | 31 | 33 | 37 |
| What condition makes the press and volume of gas change? | 18 | 21 | 15 | 20 |
| How do we classify rocks? | 15 | 15 | 13 | 17 |
| Why is an air balloon lifted when it is heated? | 23 | 21 | 23 | 27 |
| How can we observe a cell with a microscope? | 55 | 59 | 56 | 50 |
| What is the difference between a vegetable cell and an animal cell? | 21 | 24 | 23 | 13 |
| How does the destruction of ozone layer affect human life? | 39 | 47 | 42 | 24 |

## Topics that interest students (Level 3)

| Which of the following topics interest you? | All (%) (N=350) | High (%) (N=95) | Mid (%) (N=172) | Low(%) (N=83) |
|---|---|---|---|---|
| How do we induce static electricity? | 17 | 20 | 19 | 7 |
| The principal of magnetic levitation train | 34 | 42 | 31 | 24 |
| The difference between solids and liquids dissolving | 13 | 14 | 13 | 11 |
| How cloud and fog are formed? | 31 | 25 | 34 | 24 |
| How do we gain petrol from crude petroleum? | 12 | 14 | 11 | 10 |
| How does human blood circulate? | 38 | 35 | 35 | 42 |
| How the destruction of the Amazon forest affects the ecosystem? | 42 | 34 | 46 | 39 |
| How can we observe a solar eclipse? | 37 | 44 | 34 | 30 |

## Students' favourite type of lesson or activity

| | (1) First (%) | | (2) Second (%) | | (3) Third (%) | | (1)+(2)+(3) | |
|---|---|---|---|---|---|---|---|---|
| | Level 1 | Level 3 | Level 1 | Level 3 | Level 1 | Level 3 | Level 1 | Level 3 |
| Listening to lecture | 9 | 12 | 6 | 8 | 12 | 12 | 27 | 32 |
| Discussion | 4 | 7 | 6 | 9 | 9 | 8 | 19 | 24 |
| Individual task | 1 | 1 | 2 | 1 | 4 | 4 | 7 | 6 |
| Solving exercises and problems | 3 | 2 | 6 | 5 | 7 | 8 | 16 | 15 |
| Watching science video tape | 18 | 23 | 20 | 21 | 18 | 14 | 56 | 58 |
| Making equipment or model | 10 | 13 | 26 | 20 | 18 | 20 | 54 | 53 |
| Group task | 5 | 4 | 8 | 8 | 14 | 13 | 27 | 25 |
| Laboratory | 47 | 34 | 23 | 24 | 10 | 13 | 80 | 71 |

## Level 1 students' favourite type of lesson or activity against high, middle and low working memory space

| | (1) First (%) | | | (2) Second (%) | | | (3) Third (%) | | | (1)+(2)+(3) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Mid | Low | High | Mid | Low | High | Mid | Low | High | Mid | Low |
| Listening to lecture | 6 | 9 | 10 | 9 | 5 | 3 | 22 | 9 | 6 | 37 | 23 | 19 |
| Discussion | 4 | 4 | 3 | 5 | 7 | 5 | 6 | 10 | 10 | 15 | 21 | 18 |
| Individual task | 0 | 2 | 1 | 0 | 2 | 2 | 2 | 5 | 4 | 2 | 9 | 7 |
| Solving exercises and | 2 | 2 | 4 | 5 | 5 | 7 | 9 | 8 | 5 | 16 | 15 | 16 |
| Watching science video tape | 16 | 14 | 27 | 20 | 20 | 20 | 15 | 21 | 16 | 51 | 55 | 63 |
| Making equipment or model | 12 | 11 | 4 | 35 | 24 | 22 | 15 | 16 | 22 | 62 | 51 | 48 |
| Group task | 4 | 6 | 4 | 5 | 7 | 11 | 12 | 16 | 11 | 21 | 24 | 26 |
| Laboratory | 55 | 46 | 41 | 19 | 24 | 25 | 10 | 9 | 13 | 84 | 79 | 79 |

**Level 3 students' favourite type of lesson or activity against high, middle and low working memory space**

| | (1) First (%) | | | (2) Second (%) | | | (3) Third (%) | | | (1)+(2)+(3) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Mid | Low | High | Mid | Low | High | Mid | Low | High | Mid | Low |
| Listening to lecture | 8 | 15 | 8 | 6 | 9 | 10 | 18 | 11 | 10 | 32 | 35 | 28 |
| Discussion | 7 | 9 | 2 | 4 | 11 | 13 | 12 | 8 | 4 | 23 | 28 | 19 |
| Individual task | 0 | 1 | 2 | 0 | 1 | 0 | 4 | 2 | 7 | 4 | 9 | 9 |
| Solving exercises and | 3 | 3 | 0 | 3 | 7 | 2 | 4 | 8 | 13 | 10 | 23 | 15 |
| Watching science video tape | 20 | 19 | 33 | 21 | 20 | 22 | 17 | 17 | 16 | 58 | 56 | 71 |
| Making equipment or model | 18 | 11 | 13 | 24 | 21 | 13 | 13 | 22 | 24 | 55 | 54 | 50 |
| Group task | 6 | 3 | 5 | 6 | 8 | 10 | 12 | 15 | 11 | 24 | 26 | 26 |
| Laboratory | 33 | 37 | 30 | 28 | 23 | 23 | 16 | 12 | 16 | 77 | 72 | 69 |

# Appendix D

# Applications-led-course

# Scottish Standard Grade Physics Arrangements (revised 2004)

*Unit 1: Telecommunication*

The purpose of this Unit is to assist pupils to gain understanding of the physical principles, which underlie the rapidly developing area of information technology. Among the aspects studied are radio and television reception, communication satellites and the use of fibre optics for transmitting information.

*Unit 2: Using Electricity*

This Unit allows pupils to gain a knowledge and understanding of the principles behind the electrical and electronic devices, which they encounter in their everyday lives. Since these principles are developed further in later Units, the emphasis in this Unit is on providing a sound foundation of electrical circuit theory.

*Unit 3: Health Physics*

It is hoped that an awareness of the beneficial and caring face of physics will balance the negative view that physics only relates to the production of weapons of mass destruction. At the same time, this Unit is especially important as a preparation for life as it introduces pupils to the uses of ultrasonics, optics, electronics and radioactivity in medical care.

*Unit 4: Electronics*

Developments in the field of microelectronics have revolutionised the structure of commerce and industry. This Unit attempts to familiarise pupils with developments in both digital and analogue electronics and provides further applications of the circuit theory developed in Unit 2. The associated practical activities allow pupils to investigate what "chips" can do and to recognise how they can be linked together as elements in a total system. Theoretical aspects of solid state physics are not considered appropriate at this level.

Unit 5: Transport

This Unit is similar in nature to Unit 2 in that it introduces fundamental concepts, which can be developed further in later Units. The main aim is to provide a grounding in key concepts of mechanics and to relate these to everyday aspects of travel such as the use of seat belts and the stopping distances of vehicles.

*Unit 6: Energy Matters*

The provision of an adequate supply of energy and its careful husbanding is one of the most important problems facing a modern, highly-industrialised society. This Unit enables pupils to study energy supply and demand, the generation of electricity and the physical principles involved in conservation, especially in the domestic environment.

*Unit 7: Space Physics*

This final Unit endeavours to instill in pupils a sense of wonder about the vastness of the Universe and to develop an appreciation of the ways in which knowledge has been obtained about the constitution of stars. Our trips into near space provide a context in which to consider the physical basis of space travel.