Inculcating and Encouraging the Use of Critical Thinking Skills in Science Student Teachers in Malaysia

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ABSTRACT

Malaysia is a multi-racial, largely Muslim, country rapidly emerging from a colonialist past and preparing itself to compete in a global society. The Malaysian government whilst striving to retain its moral and cultural identity has recently introduced long term plans through its Vision 2020 programme, giving direction to its educational thrust at primary, secondary and tertiary levels well into the new millennium. It is envisaged that important among the skills Malaysians will need to have to take advantage of their new position in the world order is the ability to think creatively and critically and be capable of solving problems and making decisions between an awesome array of choice. The importance of education in developing such skills is explicitly recognised in Vision 2020. This thesis looks specifically at how this might be accomplished in the training of secondary school science teachers.

This study uses an array of instruments, including the California Critical Thinking Disposition Inventory, the Cornell Critical Thinking Test, Level X, the Science Teaching Observation Schedule, and a number of instruments specifically developed for the study, all of whose reliability and validity are carefully established. The study seeks to explore the effectiveness of an intervention strategy in changing pre-service science teachers' dispositions towards critical thinking, their level of professional knowledge and understanding of critical thinking in the secondary science curriculum, and their changing behaviour in the science classroom as a result of this intervention strategy.

Using a *quasi- experimental* research design, data is collected from some 142 science student teachers in the Universiti Kebangsaan Malaysia. The students were sub-divided into a control and two experimental groups, the latter receiving two different instructional programmes. Multiple analysis of variance techniques demonstrated a correlation between intervention strategy and improved attitude scores, and a corresponding increase in knowledge about the teaching of critical thinking and a limited but educationally significant increase in specific critical thinking skills. A factor analysis of classroom based observation data showed that the students predominantly employed three teaching styles called the "Enquirer Mode", the "Problem Solver Mode" and the "Informer Mode" with considerable overlap between them. It was not possible to relate these teaching styles to the intervention strategy or their critical thinking dispositions.

It was concluded that critical thinking is a viable element of the teacher training curriculum, but that it needs to pervade the entire teacher training curriculum rather than being introduced in "bolt on" fashion as was necessitated by the nature of this study.

DECLARATION

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning

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DEDICATION

MY FATHER & MOTHER

"My Lord! Bestow Thy Mercy upon My Parents
As They Raised Me Up When I Was Little"
(Al Quran, 17: 24)

MY LOVING HUSBAND

For Rekindling My Life. . .

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The most satisfying moment of writing a thesis is the opportunity to thank those who have had a hand in one way or another in its final production. I do so now not out of customary practice but out of sincere and humble gratitude. Unfortunately, a list of appreciation, no matter how extensive, is never exhaustive, and this acknowledgement is no exception.

My foremost gratitude goes to my supervisor, Professor Dr David Reid, who has guided and consoled me unstintingly throughout the course of this study. I owe my extreme indebtedness for his sincere willingness to channel and share with me his high academic standards and aspirations, which enlightened the path towards the successful completion of this thesis.

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I extend my deep indebtedness to Puan Rozlina Tan, Puan Norsimah, Dr Faridah Serajul Haq and Dr Mohamed Amin Embi who have invested a great deal of their valuable time translating the standardised instruments which has been the platform for this thesis. Words of great appreciation also go to En Rashidi Azizan and the students of the BSc. Programme at the Universiti Kebangsaan Malaysia for their significant participation in testing and contributing to the outcome of this thesis, not only to the benefit of this thesis, but to all those who seek knowledge for the betterment of the nation.

I am also immensely grateful to the Universiti Kebangsaan Malaysia for trusting and providing me with the necessary funds without which it would not have been possible for me to complete this course of study.

Further credit and deeper thanks should also go to my family members for their continuous prayers, sustained help and understanding during the undertaking of this study. For them, all these efforts have been most worthwhile.

And lastly, but by no means least, my unequivocal appreciation goes to my husband who encouraged me to take up this challenge for the quest of knowledge and whose love, continuous support and invaluable advice has sustained me throughout, and resulted in the completion of this study.

LIST OF ABBREVIATIONS

CCTDI	**C**alifornia **C**ritical **T**hinking **D**isposition **I**nventory
CCTT, Level X	**C**ornell **C**ritical **T**hinking **T**est, Level X
CoRT	**Co**gnitive **R**esearch **T**rust
IPSC	**I**ntegrated **P**rimary **S**chool **C**urriculum
ISSC	**I**ntegrated **S**econdary **S**chool **C**urriculum
ISSSC	**I**ntegrated **S**econdary **S**chool **S**cience **C**urriculum
MI	**M**odularised **I**nstruction
OscAR	**O**bservation **S**chedule **A**nd **R**ecord
STOS	**S**cience **T**eaching **O**bservation **S**chedule
SITC	**S**ultan **I**dris **T**raining **C**ollege
T	**T**ruth Seeking
O	**O**pen Mindedness
A	**A**nalyticity
S	**S**ystematicity
C	Self **C**onfidence
I	**I**nquisitiveness
M	**M**aturity

ABOUT THE CANDIDATE

The candidate holds a BSc. (Hons) degree in Science Education from the Universiti Kebangsaan Malaysia in 1992 and possesses two years experience in teaching Science at upper secondary school level. In 1994, the candidate joined the Faculty of Education, Universiti Kebangsaan Malaysia as a tutor in Science and Educational Measurement and Evaluation, and she was later granted a scholarship to further her studies. She was awarded her Masters degree in Science Education by the University of Manchester in 1995.

EDUCATION AND TEACHER EDUCATION IN MALAYSIA

1.1. INTRODUCTION

Changes and reformation in education are as inevitable in Malaysia as anywhere else in the civilised world. Such changes and reformation are triggered by internal and/or external forces in various forms over generations. Education reformation in Malaysia, on the one hand, is similar to those of other colonised countries. On the other, however, due perhaps to the multiracial composition of its population, coupled with the government effort to foster *esprit de corps* among the major groups of people (Malay, Chinese and Indians), significant contrast does occur.

Reformation in Malaysian education can be discussed under two major sub-headings: the pre-colonial and colonial era, and the post independence era; each era has embodied particular values in the objectives attaching to the educational processes of its time. Being an integral part of the school system, and since teachers provide an important bridge between the government and the population, reformation in the school system is often accompanied by changes in teacher education so that teachers become competent to deliver what is envisaged by reformation. In this sense, education, including teacher education, can be argued to be as justifiably of political interest in Malaysia as it is increasingly in the west, and in particular in the United Kingdom.

1.2. EDUCATION IN MALAYSIA: A RETROSPECTIVE

1.2.1. The Pre Colonial Era (Pre 1784)

During the pre-colonial era, any formal educational system within what is now Malaysia was almost non-existent, except for that provided by the religious schools. Malay[1] children who attended the religious schools, commonly known as *Quranic* schools, learnt Arabic language by reading and reciting the Quran, its laws and traditions (Hoy Kee and Yee Hean, 1972). At times, the children were exposed to

[1] The Malays are the major indigenous population in Malaya

small amounts of the Malay language, handicrafts and some apprenticeship in agriculture. The religious teachers, the *Hadjee* or *Khatib*, though having sound religious knowledge, did not have any formal training in teaching methodologies, and were able to exert autonomy in their use of curriculum and assessment procedure. There was neither public concern nor government interference.

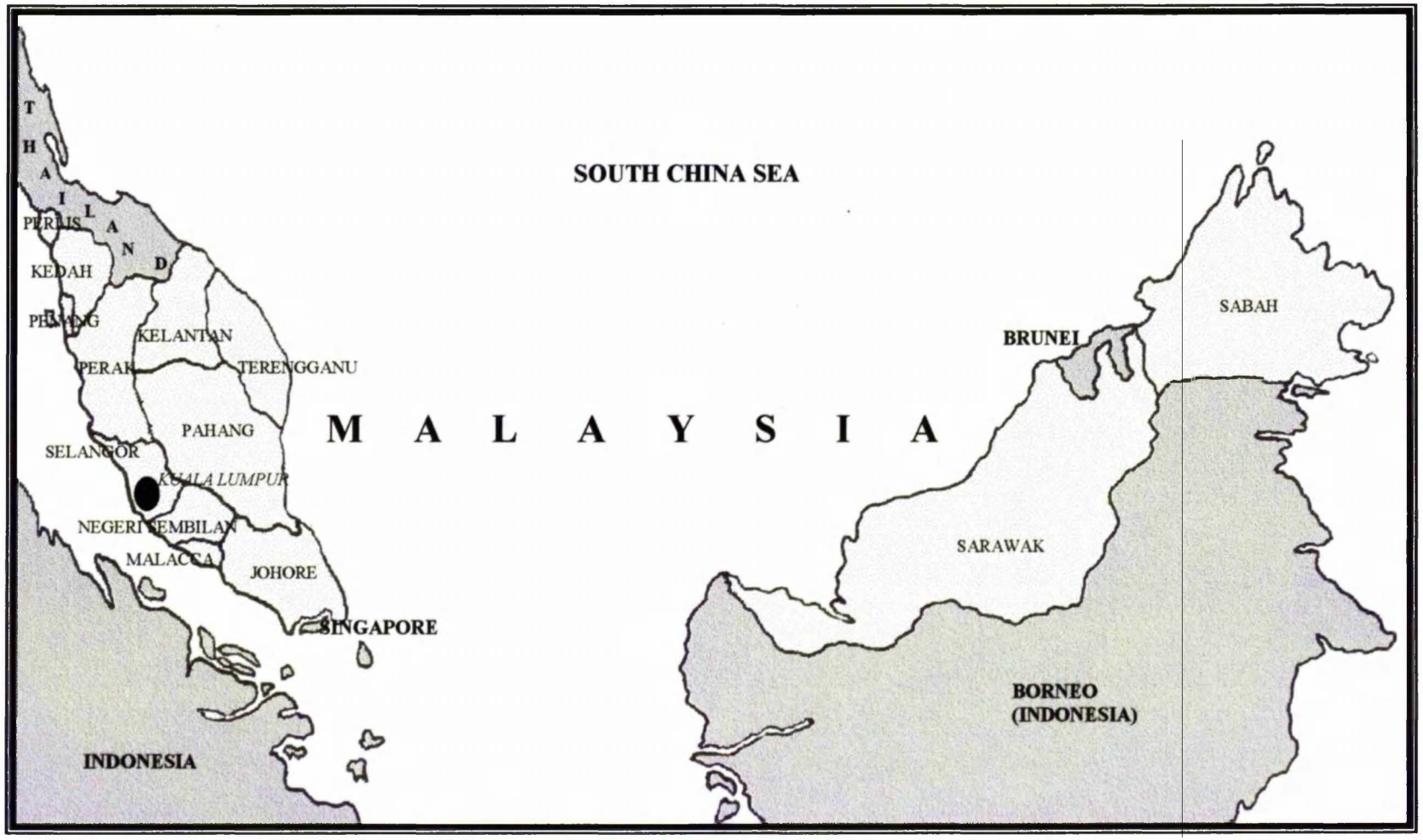
Homogenous in terms of its clientele, education was conceptualised as a means of transmitting Islamic knowledge and values *per se*. This was felt appropriate for a self-sufficient traditional Malay society since all the administration posts were monopolised and inherited by the nobility. For the greater part of the population, the children would grow up and inherit the traditional economic activities of their ancestors: fishermen or peasants within their village economy.

1.2.2. The Colonial Era (1784 – 1956)

Though the British were already in contact with the Malay Peninsula through trading long before 1784, their presence was really felt when Penang, one of the states of the Malay Peninsula, fell into British hands. By 1914, British sovereignty had encompassed the whole of the Malay Peninsula, Sabah and Sarawak (see FIGURE 1.1). Large numbers of immigrants were brought from India and China to supply manpower needs in the expanding tin and rubber industries. The presence of these newcomers diversified the societal climate and increased the population dramatically (Gullick, 1963). In order to meet the literary demand of this newly created multi-blended society, four different types of education came to be established, the English School, the Malay Vernacular School, the Chinese Vernacular School and the Tamil Vernacular School.

To cater for the expansion of the British administration and the rapid growth of trade in the region, it was found necessary to recruit new and more local personnel especially for the lower end of the administration (for instance clerks, minor officials and subordinate agricultural staff). To meet this increasing demand, English medium

FIGURE 1.1: MAP OF MALAYSIA



schools began to appear. Penang Free School was the first English school, established in 1816. Subsequently the number of English medium schools increased rapidly throughout the country; private enterprise and the influence of Christian missionaries were both heavily involved in establishing the schools (Seng Ong, 1964). These fee paying town schools were open to all races and creeds. The curriculum, textbooks and teachers were imported directly from Britain, and the children had to sit the same examinations as their British counterparts.

At a platonic level, the opening of English medium schools provided the potential for equal education opportunities for the whole population of the Malay Peninsula regardless of race and religion. However, deeper inspection reveals that only a tiny fraction of the population could afford to send their children to these English medium schools; the better paid urban dwellers. Thus, the English medium school cohorts were derived mostly from Chinese business families and Malay elites. Therefore the manifestation of the English medium school, it was argued, was the creation of a new breed of "Malayan elites", created to service the administrative and bureaucratic machinery of the colonial government.

Being the indigenous population of Malaya[2], education of the Malays received special attention from the British. Under the British "*paternalistic protectionism policy*" (Thomas, 1983), the Malay branch of the Penang Free School was established in 1821. The mission of establishing Malay schools was mainly to inculcate into the Malays the habit of punctuality and good behaviour while totally neglecting Islamic norms and values (Hoy Kee and Min Phang, 1975). The main cognitive aim as evidenced in one of the official statements (cited in Salleh, 1979) was merely a removal of illiteracy at the very minimum:

[2] Before the formation of Malaysia in 1963, the Malay Peninsula was called Malaya

> "The curriculum of work will be seen ... to be very elementary, but it is sufficient for the ordinary requirements of Malay boys, who will become bullock-wagon drivers, padi-growers, fishermen etc., and enables them by the time they have passed the fourth standard to read or write the simple literature of their mother tongue either in Jawi or Roman character, to keep accounts if they become small shopkeepers, and to work simple problems in the money currency, weights and measures of their country"
>
> (Special Report on Educational Subjects, 1905)

Sequentially planned for a duration of four years, the subjects taught were highly concentrated on the three R's, namely Reading, Writing and a little Arithmetic. Most of the teachers were untrained and the standard of teaching was relatively low. Such was the situation that enrolment in the Malay vernacular schools was discouraged.

The year 1871 marked an important turning point in the development of Malay vernacular schools when Islamic education and the existing curriculum became integrated (Chelliah, 1947). The content of the curriculum was widened to include Geography, Hygiene, Drawing, Gardening, Basketry, Sewing, and Cooking. Although the curriculum had a strong industrial bias, the main objective of the curriculum remained the same; that was to maintain the inheritance of traditional Malay economic activities. The majority of the children who completed primary school had limited access to further advancement since there were no secondary Malay schools available. Only a small number would manage to further their education to teacher training colleges to become teachers who would later on take the role of the religious masters. Education in Malay vernacular schools, it is argued, did not function as an instrument in social engineering; no social mobility was expected. The hidden idea underpinning the curriculum was merely the preservation of Malay's traditional way of life.

As for the Chinese and Indians, the British felt it was not their obligation to provide education to these two groups since they were regarded as being temporary immigrants. Due to this British *laissez-faire* attitude (Hoy Kee, 1973), the Chinese and Indians had to build schools at their own expense, which in turn led to the emergence of the Chinese and Tamil vernacular schools. The first modern Chinese vernacular school was opened in 1900 in Kuala Lumpur (Treggoning, 1964), whereas

the Tamil vernacular schools had their roots as early as 1816 (Hoy Kee and Min Phang, 1975). Teachers and textbooks were directly imported from China and India respectively and the curricula were closely patterned on those in the respective motherlands. The British, however, had little objection to this since it would encourage a certain disunity among the three major groups and thus further strengthen their colonial supremacy in Malaya.

Towards the end of the colonial era, it was clear that the entrenchment of fragmented and hierarchical educational structures were reinforcing the social stratification among the population. Being at the top of the education pyramid, English school graduates were presented with more promising and multi varied career prospects, compared to the majority of their vernacular counterparts who would continue to take over the traditional roles of their fathers. The Malays remained as farmers and fishermen, the Chinese in mining and trades while the Indians worked in the rubber plantations. This anticipated repercussion of reinstating the children into their own milieu was seen by the British as part of a coherent and explicit *divide and rule* policy (Mahathir, 1998).

The British returned immediately to Malaya after the Second World War ended. However, the war had brought with it a spirit of nationalism throughout Southeast Asia. The Malays quite rightly as it had transpired felt the British were incapable of defending Malaya in the face of foreign invasion, and the success of the Japanese had degraded the supremacy of the British in the eyes of the Malays. Realising this, the British returned to Malaya with a commitment to prepare the country for self-government and eventual independence. In an attempt to create a harmonious social and political climate in a multi-racial country, it was argued that educational opportunities should be available to the whole population and be geared towards the inducement of a sense of camaraderie and unity within the country. The four distinct types of education that had been established during the colonial era came to be regarded not as hindrances, but as a "starting point" towards the

nourishment of a sense of understanding of the richness of the cultures and traditional values that exist in a multi racial society.

In 1952, recommendations submitted by the Barnes Committee on Malay Education (1951), Fenn-Wu on Chinese Education (1951), and Tamil Education Committee (1952) were welded together and an *Education Ordinance of 1952* was formulated. Parallel with its theme to utilise education as a unifying factor towards a united Malayan nation, primary education was made compulsory for all children between the ages of six and twelve in two types of national schools one in which Malay would be the medium of instruction and the other in which the medium of instruction would be English. Bilinguals in English and Malay were stimulated by making English a compulsory subject at Malay schools and *vice versa.* However, preservation of Chinese and Indian cultures was maintained by allowing instruction in Chinese and Tamil if requested (Marzuki *et al.*, 1994).

The codification of these new educational policies signalled the opening of an era in the development of education in Malaya. Cognisance of the importance of language as a powerful instrument by which not only individuals may express their personality, but groups may also identify their collective consciousness necessitates the conversion of the vernacular schools into national schools. However, the realisation of this ideal was problematic. Dissatisfaction arose especially from the Chinese groups and a shortage of teaching personnel capable of teaching English and Malay coupled with an increase in national expenditure together ensured that the new scheme was impossible to operationalise.

1.2.3. Early Independence Era (1957 - 1970)

Malaya received its autonomous status in 1955. With the attainment of self-government, it became politically imperative to formulate a National Education Policy that would navigate the course of the educational process, for it was to education the government looked upon as a device to bring together children of all

races in which the national language was to be the main medium of instruction. In realising this aspiration the Razak Committee was then set up in 1956 with the aim of establishing

> "a national system of education acceptable to the people of the Federation as a whole which will satisfy their needs and promote their cultural, social, economic and political development as a nation, having regard to the intention to make Malay the national language of the country whilst preserving and sustaining the growth of the language and culture of other communities living in the country"
>
> (Razak Report, 1956; p.2)

Comprehensive in terms of its long-term objectives, national unity was to remain its co-ordinating theme. A common content syllabus was introduced and compulsory study of the Malay language as the national language was emphasised. Education was conceptualised as a means by which a sense of solidarity and national consciousness would be evolved. A deeper awareness and understanding of cultures and traditions and differentiation in the communities would be implanted and the children of all races would be orientated and assimilated to a Malaysian culture. It was considered that there was an important need to unify the various people that constituted the newly independent Malaysian nation, which, in turn, would make for social and political stability, thus leading to economic prosperity.

The Razak Report (1956) was also seen as a great leap towards eradicating racial sentiment among the various groups through the democratisation of education. Equal financial support was granted and similar training amenities were provided to all teachers. Higher education was opened to all by the extension of English language instruction to all schools and the provision of equal opportunities for promotion to secondary schools. Another major contribution of the Razak Report (1956) was the reorganisation and development of technical schools to produce skilled manpower for agriculture and industries. Local Education Authorities were set up to promote primary education in the community (Hoy Kee and Min Phang, 1975). These authorities were supported by an Independent Inspectorate, which was specifically appointed to monitor the standard of education and henceforth monitor the increasing literary level of the newly independent nation. This was evidenced in the upward

movement of the total population enrolment percentage from 11.2% in 1950 to 17.6% in 1960 (UNESCO, 1969). The Razak Report (1956) was then accepted as *Education Ordinance of 1957* and became the National Education Policy for independent Malaysia.

In 1960, another committee headed by Abdul Rahman Talib was set up to review the implementation of educational policies enacted by the Razak Report. This committee recommended the continuation of educational policies laid down by the Razak Report and as an addition, two major new recommendations were made; viz. the introduction of a universal free primary education and the raising of the school-leaving age to 15 (Marzuki *et al.*, 1994). The recommendations of both the Razak and the Abdul Rahman Talib Reports constituted the foundation of the *Education Act of 1961*.

Another major development in the educational system occurred in 1965 with the introduction of a comprehensive school system (Marzuki *et al.*, 1994). The recommendation to raise the school leaving age to 15 was materialised with the termination of the Malayan Secondary School Entrance Examination and made for a nine-year common schooling programme; with six primary years and three lower secondary years (Hoy Kee, 1973). At this latter level, children were introduced to both academic and prevocational subjects. The main aim was to equip the children with the skills and knowledge required for participation in the economic activities of the country. It could be said that such farsighted policies were immediately successful in breaking down the racial inequalities, which had increased under colonial rule. After 12 years of independence, serious rioting took place on the 13 th May 1969. These riots catalysed the Malaysian Government into further action and it formulated and implemented the New Economics Policy (NEP) in 1970, whose objectives were the eradicating of poverty irrespective of race and the restructuring of society to eliminate the identification of race with economic function (Mahathir, 1998). Through the NEP, the government hoped to promote socio-economic progress to upgrade the quality of life of the whole population and generate economic

equilibrium within the multi racial society. Once again, it was the education system that was seen to be pivotal in the provision of the means by which those objectives were to be realised.

Thus it was that immediate post-independence concern led to the establishment of a unified educational system symbolised by a common language, a common curriculum and a common examination system. In an effort to establish these kind of national schools, the state took control of the curriculum and the medium of instruction. This was accompanied by a rapid expansion of mass schooling and higher education. This expansion came about because of an increased awareness of the importance of education in changing societal attitudes, not only as a unifying factor in a multi blended society, but also as an agent for social mobility. It must be said too that increasing demands for skilled manpower also helped shape the agendas and reformations of the school system.

1.2.4. The 1980*s*

Whilst this curriculum was being implemented, monitored, evaluated and adjusted, a Cabinet Committee had been set up in 1974, whose specific mission was to study how far the existing educational practices had fulfilled national needs and at the same time were fostering the cultural, social, economic as well as the political growth of the nation. Five years later, the committee completed its study and the findings and recommendations were nationally announced as the Cabinet Report (1979). It was recognised that forthcoming educational change must not be directed solely by current global trends, but must also recognise elements of national relevance in order to fulfil the national needs and demands sparked by various ethnic groups that populate the country. In other words, restructuring the entire school curriculum must reflect a Malaysian identity thus satisfying the needs and aspirations of a "united, disciplined and trained society" (Cabinet Report, 1979; p.3). These recommendations then formed the thrust behind the educational objectives of the Fourth and Fifth Malaysian Plans. A year later, the New Primary School Curriculum

was introduced and in 1989, the new curriculum was extended to the lower secondary level and the new reform is known as the Integrated Secondary School Curriculum. While primary education reverted back towards a higher concentration on the 3R (Reading, Writing and Arithmetic) skills, education at the secondary level was systematically planned according to the model of a general education which encompassed an integration of a common core of knowledge, skills, and values as envisaged by the committee (Ministry of Education, 1993).

Analytical scrutiny of the new curriculum revealed that unlike in the 1960*s* and 1970*s* where the curriculum reformation significantly displayed a total "handing on" of "prized curriculum packages" from the colonial power (Ibrahim, 1981; Lee, 1992; Tan, 1991), reformation in the 1980*s*, manifested reconciliation of western and Islamic practice. A heavy absorption of western influence was not only demonstrated by the reversion to the 3R skills which could be correlated with the "back to basics" movement that was sweeping western countries but the teaching of values across the curriculum was also evidently influenced from the teaching of values across the curriculum in western countries (Goodson, 1983). Nonetheless, the insertion of moral values across the curriculum and the re-emergence of moral education was also an indication of Islamic influence on the curriculum. Such a détente was boldly articulated in the National Philosophy of Education that underpinned the 1980*s* curriculum implementation, which states that:

> "Education in Malaysia is an on-going effort towards further developing the potential of individuals in a holistic and integrated manner, so as to produce individuals who are intellectually, spiritually, emotionally and physically balanced and harmonious, based on a firm belief and devotion to God. Such an effort is designed to produce Malaysian citizens who are knowledgeable and competent, who posses high moral standards, and who are responsible and capable of achieving a high level of personal well-being as well as being able to contribute to the harmony and betterment of the society and the nation at large"
>
> (Ministry of Education, 1988; p.6)

Thus it was that educational reformation in the 1980*s* resulted from an interaction between external world cultural forces, especially from the western and Muslim countries and internal socio-political forces. This was the background in which the modern Malaysian curriculum evolved.

1.2.5. The 1990*s*

Encouraged by its success in implementing its Five Year Plans as well as the New Economics Policy which spanned a period of twenty years since 1970, Malaysia embarked on a new and more challenging phase in nation building through the guidance of a far sighted plan known as the *Vision 2020*. Being the architect of the vision, YAB Dato' Seri Dr Mahathir Mohammad, the Prime Minister of Malaysia, proactively visualised that by the year 2020, Malaysia will emerge as a fully developed nation. Thus:

> "By the year 2020, Malaysia is to be a united nation, with a confident Malaysian society, infused by strong moral and ethical values, living in a society that is democratic, liberal and tolerant, caring, economically just and equitable, progressive and prosperous, and in full possession of an economy that is competitive, dynamic, robust and resilient"
>
> (Mahathir, 1993; p.5)

It is stated explicitly that the Vision 2020 stresses development not only in terms of economic prosperity, but also national unity and social cohesion, social justice, political stability, system of government, quality of life, social as well as spiritual values, national pride and confidence (Mahathir, 1997).

It is almost axiomatic that human resource development is the key towards a developed and industrialised society (Abdullah, 1993). The history of human civilisation has taught that the character and strength of a nation is invariably linked with the quality and attributes of its citizenry. The importance of human capital as the ultimate basis wealth of a nation (Harbinson, 1993) is unequivocally stressed in the Vision 2020, which states that:

> "...it is blindingly clear that the most important resource of any nation must be the talents, skills, creativity and will of its people. What we have between our ears, at our elbow and in our heart is much more important than what we have below our feet and around us. Our person is our important resource. Without a doubt, ...Malaysia must give the fullest emphasis possible to the development of this ultimate resource"
>
> (Mahathir, 1991; p.7)

Realising the importance of human resource development in its mission to produce a mature Malaysian society, "diligent and resourceful and which can initiate, direct and

propel economic growth and yet remain uniquely Malaysian", the Prime Minister outlined nine central strategic challenges to galvanise the efforts of all Malaysians. These challenges are:

- Establishing a united Malaysian nation with a sense of common and shared destiny;
- Creating a psychological liberated, secure, and developed Malaysian society with faith and confidence in itself, justifiably proud of what is accomplished, robust enough to face all manner of adversity;
- Fostering a mature democratic society, practising a form of mature consensual, community oriented Malaysian democracy that can be a model for many developing countries;
- Establishing a fully moral and ethical society, whose citizens are strong in religious and spiritual values and imbued with the highest of ethical standards;
- Establishing a matured, liberal and tolerant society in which Malaysians of all colours and creeds are free to practise and profess their customs, cultures and religious beliefs and yet feeling that they belong to one nation;
- Establishing a scientific and progressive society, a society that is innovative and forward-looking, one that is not only a consumer of technology, but also a contributor of the scientific and technological civilisation of the future;
- Establishing a fully caring society and a caring culture, a social system in which society will come before self, in which the welfare of the people will revolve not around the state or the individual but around a strong and resilient family system;
- Ensuring an economically just society in which there is a fair and equable distribution of the wealth of the nation, in which there is a full partnership in economic progress; and
- Establishing a prosperous society, with an economy that is fully competitive, dynamic, robust and resilient.

Within the domain of this discussion, it is posited that the most relevant challenge is to establish a scientific and progressive society; a nation that is innovative and forward looking, one that is not only a consumer of technology, but also a contributor to the scientific and technological civilisation of the future.

In order to develop "what Malaysians have between their ears, at their elbow and in their heart" in their quest towards establishing a scientific and technological conscious society, essential changes had to be made to existing educational training and policies. Thus in the Sixth Malaysian Plan (1991-1995) and later continued in the Second Long-Term Perspective Plan, Malaysian educationalists undertook the task of amending the existing curriculum which now placed priority on Science and

Technology education without affecting the main objectives of education as envisaged by the Cabinet Committee. As a result, the Malaysian to be generated by the school system will not only be equipped with knowledge and skills in Science and Technology, but will also demonstrates a flair for creativity, flexibility and analytical capacity in making a morally effective contribution to the development of the country's harmony and prosperity (Ministry of Education, 1990).

It is envisaged that future Malaysians will possess and utilise the tools to think creatively and critically, while at the same time be capable of solving problems and making just decisions. All these are seen to be invaluable assets (Mahathir, 1996) as the world enters an Information Age, where the key to success in this age will be making the right judgement between an awesome array of choices.

1.3. THE EVOLUTION OF TEACHER TRAINING COLLEGES/ INSTITUITIONS IN MALAYSIA

1.3.1. Introduction

Before the attainment of independence, neither a coherent nor unified pattern of teacher training was established in Malaysia. The evolution of teacher training institutions in Malaysia was highly correlated with the development of its main clientele; viz. the school system. Just as the four systems of schools developed independently of one another, teacher-training institutions also followed a similar pattern of development. The development of the teacher education programme can be divided into two phases. Phase One occurred when teacher education was initiated in an *ad hoc* manner in order to meet the specific and short-term contemporary demands of specific objectives of schooling. There were neither authoritative bodies nor educational policies that underpinned its implementation. At this initial stage of development, multi-pattern teacher training programmes reflected the appearance of different types of training courses for different type of schools using different media of instruction. Rather interestingly, within the same types of schools, there were different types of training programmes, each geared to a particular need or purpose.

Phase Two was by contrast more co-ordinated and on a larger scale. Following the end of Phase Two, a more rigid and comprehensive system of teacher training developed and expanded beyond racially differentiated media of instruction.

1.3.2. On Looking Back

Early ventures into formal teacher training started in 1878 when the first Malay Teacher Training College was established in Singapore. The first recruitment was mainly the *Hadjees* and *Khatib*s who instructed the Quran, who in most cases possessed a slight knowledge of reading and writing, but none of arithmetic. The minimal entry requirement was Standard Five. Candidates were appointed as assistant teachers under the supervision of experienced *Hadjees* and *Khatib*s. Subjects taught were mainly Arithmetic, Romanised Malay, Geography and school rules. Real life classroom experiences were designed through a series of teaching practices. The inception of the Malay Teacher Training College meant that schools were gradually furnished with increasing numbers of qualified teachers. Despite supplying more than 53% of trained teachers' requirements in British Malaya, the College was closed in 1895 due to retrenchment measures (Sanusi, 1955; Salleh, 1972).

As the old and dogmatic religious tradition of learning among the Malays changed, the needs of formal schooling became more significant. This situation catalysed the opening of another teacher training college in Taiping, Perak in 1898. This provided a two-year training programme, which was designed both to provide a professional training and also to strengthen candididates' knowledge and understanding of Malay school subjects including Malay Literature. In conjunction with the introduction of an industrially biased curriculum, courses on manual instruction in carpentry, bamboo and cane work were also introduced one year before the termination of the programme in 1900. However, these innovations turned out to be little more than *ad hoc* responses to short term perceived needs.

The first long-term provision of a teacher-training programme was initiated by R.J Wilkinson who was then the Acting Inspector of Strait Settlement Schools[3] (1889 - 1900). In 1900 Malacca Training College was established, followed thirteen years later by Matang Training College. The main objectives of the curriculum of the colleges were to render the students conversant with the best Malay Literature and arithmetical principles and to equip them with the principles and practice of school management including the element of drawing and some manual work. Despite countless effort by its founder, the prime contribution of the colleges towards the development of teacher education was merely as a pool of supplying teachers for the Malay vernacular schools. The objective of producing quality teachers largely failed and the standard of teaching remained unchanged (Salleh, 1979). Both the Malacca and the Matang Colleges were closed in 1922 and replaced by an amalgamated and centralised college called Sultan Idris Training College at Tanjung Malim Perak.

Just like its predecessor, the opening of Sultan Idris Traning College (SITC) was due to extensive efforts by a foreign innovator, this time R.O. Winstedt, the Assistant Director of Education (1916) who was in charge of the Malay Vernacular School. The college was established at a time when the structures and objectives of Malay schools were being completely redefined by the government. Equipped with its Translation Bureau and experienced teaching staff, the college was modelled on the lines of the English public schools which trained Malay students for service as schoolmasters in the Malay vernacular schools. During the three-year training programme, student teachers were taught mainly about Malay subjects including general knowledge and Religious instruction. In preparing teachers for the new challenge of moulding Malay boys for the environment to which they belonged; viz. by leading peasantry life within their village economy, practical subjects like Gardening and Basketry were made compulsory. Under the Theory of Teaching, students' adroitness in teaching skills was nurtured by the teaching of general principles of educational practice, methods of teaching various subjects and school

[3] During the British Colonial rule the three settlements of *Penang, Malacca* and *Singapore* were known as the Straits Settlements

management. Interestingly, the role of the SITC was not confined to the production of qualified trained teachers but also of prolific Malay writers and skilful translators.

It is worth pointing out that the trainees of these early teacher-training colleges were mainly Malay boys. The training of Malay girls only started 57 years after the first training college for Malay boys was opened. This phenomenon occurred due to the attitude of Malay parents towards female education (Hoy Kee and Phang, 1975; Yaakob and Ayob, 1990). The need for trained women teachers only became apparent in the 1930*s* when the number of girls' schools had increased to 150 throughout the country. In 1935, the first Womens Teacher Training Centre was opened in Malacca. In an effort to encourage enrolment among Malay girls, the curriculum was biased towards domestic science and life around the house. Although the number of teachers produced at this early stage was low, the main objectives of its establishment were fulfilled; to open girls' minds to the importance of education (Salleh, 1979; Hoy Kee and Phang, 1975) and break the cycle of male domination in Malay society. Up to 1957, the Sultan Idris Training College and Malay Women Training College became the nuclei of the training of teachers in British Malaya particularly for the Malay vernacular schools.

No formal training for the Chinese vernacular school teachers existed before 1920 (Hoy Kee and Phang, 1975). Teachers were imported directly from China to fulfil the needs of Chinese education while at the same time maintaining the Chinese traditional heritage. To cope with the increasing demand of primary education due to the rapid expansion of the Chinese population, it was deemed fit to train the teachers locally through Simplified Normal classes which later became known as Normal Classes. These Normal Classes, attached to the Chinese High Schools, were held during the weekend for a duration of four years. The same scenario took place for the Tamil vernacular schools. Localised training started in 1937 with the opening of two-year part time Normal Classes training centres.

A systematic teacher-training programme for English schools had been initiated following the recommendations of the Wooley Committee (1870). Two-year Normal Classes were introduced for intending primary teachers in Singapore (1907), Penang (1913) and Malacca (1913). At the secondary level, teachers were mostly recruited from the University of Hong Kong. Localised and comprehensive training programmes for English secondary schools started when Raffles College was established in 1928. It soon became an important source of graduate teachers until the establishment of the Universiti Malaya in 1948.

Beginning with the early Normal Classes, the establishment of teacher training colleges clustered around the Straits Settlements as opposed to the Federated Malay States and Unfederated Malay States[4]. While the Chinese and Indians had to set up teacher training programmes at their own expense, the colonial paternalistic policy benefited Malays. The Teacher Training College provided the highest educational level ever offered for the Malays since there were no secondary Malay schools. In other words, teacher-training colleges were a symbol of progression and development of Malay education, which later led to the proliferation of the spirit of anti-colonial and national consciousness. They thus play a very important role in the evolution of education in Malaya.

1.3.3. The Emergence of a Recognisable Teacher Training Programme

The English viceroys only initiated secondary teacher education in British Malaya after the outbreak of the Second World War. One of the most striking actions of the Education Ordinance of 1952 was the establishment of a prototypical full time multi racial residential training college to train secondary school teachers. An emergency Training College at Kirby, Liverpool was the first to materialise as a result of a collaborative effort between the Ministry of Education in Malaya and the University of Liverpool. Candidates were chosen among those who had a minimum

[4] Federated Malay States: Selangor, Perak, Negeri Sembilan and Pahang
Unfederated Malay States: Perlis, Kedah, Kelantan, Trengganu and Johore

qualification of the University of Cambridge Overseas Certificate with credit in English Language. Although the programme was established in England, the curriculum was modified to suit Malayan needs and designed to equip the teacher of general subjects. The Bahasa Melayu (Malay Language) was taught as a compulsory subject and successful completion of the programme would provide a place at upper primary and lower secondary schools. Three years later, a replication programme was established locally in Kota Bharu, Kelantan. In 1955 another Malayan Teachers' Training Centre was established at Brinsford Lodge, Birmingham. These colleges terminated their operation in 1964 when the Integrated Teacher Training programme was introduced.

The opening of these three multi-racial residential training colleges marked an important turning point in the development of teacher education in Malaya. The availability of foreign premises and expertise from England made it possible to establish the first multi-racial teacher training college even whilst the country was still in a war-torn condition. For the first time, teachers of all schools were given an opportunity to be trained under the same roof. Although the use of English as the medium of instruction restricted the enrolment of the Malay candidates, the initiation of the programme nevertheless became an inspiration for the vast majority of Malay children to proceed to a primary education. As the British slowly loosened their grip, the education system in British Malaya moved towards the production of teachers who were bilingual in Bahasa Melayu (Malay Language) and English.

When the country finally gained its autonomy, a spirit of nationalism invaded the whole population. Teachers and the school system were identified as a vital element in planting the spirit of national consciousness and patriotism. Realising the importance of schools in spreading these ideas, the Razak Committee, which was set up in 1956 following the Education Ordinance of 1952, proposed the establishment of a standardised system of teacher training for all primary school teachers irrespective of the medium of instruction. Possession of Lower Certificate of Education (LCE) or School Leaving Certificate with credit in Bahasa Melayu (Malay

Language) replaced standard five, six and seven as the minimal requirement for entering teacher-training colleges. District Training Centres (DTC) were then opened throughout the country. The by now well-established Sultan Idris Training College and Womens Teacher Training College in Malacca were accredited as prime training colleges offering three year courses for LCE holders and two year courses for School Leaving Certificate holders.

A standardised system of teacher training as recommended by the Razak Report (1956) meant a minimal entry requirement, a subsequent unified salary scale, and a common syllabus for all. In this way it was hoped that the same personal attributes (attitudes and values) and professional developments (content and pedagogical knowledge) would be cultivated among teachers, which it was believed would transfer to the children of all races. Additionally, every student teacher was required to master a second language. The challenge of spreading the spirit of national consciousness led to the establishment of four types of primary teacher training distinguished by the main medium of instruction and second language (see TABLE 1.1).

TABLE 1.1

COURSES OFFERED IN ACCORDANCE WITH THE MAIN MEDIUM OF INSTRUCTION AND THE SECOND LANGUAGE

Course	*Main Language*	*Second Language*
A	Malay	English
B	English	Malay
C	Chinese	Malay
D	Tamil	Malay

The period after independence witnessed a variety of changes in education as the country prepared for the status of a developed nation. The introduction of a universal primary education and the emergence of the first cohort of young people that had undergone comprehensive education generated a disequilibrium between the supply and demand of secondary trained teachers. The incorporation of the existing secondary teacher training colleges of the Integrated Teacher Training Plan under the First Malaysian Plan (1966 – 1969), aimed to produce secondary teaching personnel in a number and variety of disciplines. Each college was permitted to specialise in particular subject areas. Such a step, emphasising subject or content knowledge, led to the identification of teacher training colleges according to the major of specialisation (see TABLE 1.2). In order to supplement the numbers of trained teachers, the Ministry of Education also launched a three-year part time Secondary Continuation Programme (1961– 1965). About the same time, a number of well-equipped secondary schools were converted into Regional Training Centres and a two-year "crash" programme (1965) was introduced.

As the 1970's approached, the prime aim of the teacher education programme was to produce sufficient numbers of secondary school teachers to cater for the needs of a newly independent nation. The effectiveness of the programme in reducing the imbalance between the supply and demand of trained teachers is marked by the reduction in employment of untrained teachers from 80 percent in 1955 to 40 percent in 1966 (Hoy Kee and Phang, 1975). Another major feature characterising the new form of teacher education programme was the emphasis on content knowledge relative to pedagogic knowledge, and candidates were selected only from those who possessed minimal qualifications in the Malaysian Certificate of Education (MCE).

TABLE 1.2

THE INTEGRATED TEACHER TRAINING PROGRAMME

Name of College	*Fields of Specialisation*
Malayan Teachers' College (Penang)	Mathematics & Science
Malayan Teachers' College (Kuala Lumpur)	English/Chinese, History, Geography & Music
Malayan Teachers' College (Johore Baharu)	Agricultural Science & Home Science
Language Institute (Kuala Lumpur)	Malay Language, History, Geography & Music (in Malay Medium)
Technical Teachers' Training College (Kuala Lumpur)	Technical & Vocational Subjects
Specialist Teachers' Training College (Kuala Lumpur)	Physical Education, Home Science, Commercial Subjects, Arts & Crafts

The main theme expressed in the 1952, 1957 and 1961 Education Ordinances was one of national unity. Education as an instrument of economic growth; as a means whereby trained manpower could be produced, only became a pre-occupation of national education policy in the 70s. However, if education is to function as an instrument of economic growth more attention needs to be paid to the development of technical and vocational education. Expected enrolment for upper secondary vocational education increased from 0.2 percent in 1965 to 4.0 percent in 1970 and by 1985 reached 25 percent. As far as general education is concerned, the ratio of Science and Arts students at the upper secondary and tertiary level was 3:2. TABLE 1.3 indicates that Malaysia is currently falling far short of the target graduate teachers

required for her schools if the production of appropriate manpower capable of contributing to Malaysia's economy, social, cultural and political development is to take place satisfactorily. Thus, in the process of restructuring Malaysia into a scientific and technological oriented society, "one of the most crucial areas of manpower resources was the graduate level teacher for upper and post secondary schools, particularly in the area of Science and Mathematics education" (Second Malaysian Plan, (1971-1975); p. 106) (see TABLE 1.3).

In order to supplement the Universiti Malaya's output of trained graduate teachers particularly in the area of Science and Mathematics, the Universiti Sains Malaysia initiated the Bachelor of Science with Education programme in 1970. This was an integrative teacher education programme where professional teaching courses were taught simultaneously with Science and Mathematics courses. In 1973, the Universiti Malaya initiated the same programme followed by the Universiti Pertanian Malaysia two years later. Meanwhile, the struggle towards the formation of the National Education System was evident by the extensive use of Bahasa Melayu (Malay Language) at all levels of schooling. The evolutionary processes of transforming the existing heterogeneous education system into a single and unique National Education System started in 1970 when all subjects in Standard One were taught in Bahasa Melayu (Malay Language) in all schools. Under the Third Malaysian Plan (1976 –1980) the conversion of National Type Schools to National Schools, characterised by a common language, common syllabi and common public examinations, was fully accomplished (Ministry of Education, 1960).

TABLE 1.3

ESTIMATED DEMAND AND SUPPLY OF TRAINED TEACHERS FOR SECONDARY SCHOOLS, WEST MALAYSIA, 1971 – 1975

	College Trained	*Graduate Teachers*		
		Arts	*Science*	*Total*
Total Available, 1970	15 238	1 468	700	2 168
Total Required, 1970	11 123	3 088	2 679	5 767
Excess (+)/Shortage (-) 1970	+ 4 115	- 1 620	- 1 979	- 3 599
Output 1971- 75	987	2 550	2 266	4 816
Losses 1971 - 75	696	54	70	124
Total Available 1971 – 1975	4 406	876	217	1 093
New Demand 1971 – 1975	3 3 11	1 070	2 025	3 095
Excess (+)/Shortage (-) 1975	+ 1 095	- 194	- 1 808	- 2 002

Source:Second Malaysia Plan, 1971 – 1975, p. 106

To summarise, the teacher education programme in the 70*s* recognised the challenge of producing teachers particularly in the areas of Science and Mathematics while promoting extensive use of Bahasa Melayu (Malay Language) across the curricula. For the first time a special committee to study the aims of teacher education had been set up (1971) whose premier task was to gravitate effort towards strengthening the quality of individual teachers and teacher education in general. It was then recommended that the expected outcomes of teacher education were teachers who "possessed positive attitudes and well rounded personalities while illustrating a sound mastery of professional skills" (Ministry of Education, 1998). In the years ahead, in order to promote a unified teacher service among primary and secondary college-trained teachers, the Integrated Teacher Education Programme was introduced. Under this scheme, the core curricula of the primary and secondary teacher trainees were integrated, with only "elective" subjects separating them from specialising either in primary or secondary school teaching (Hoy Kee and Phang,

1975). Overall, all the changes to the teacher education programmes manifested a continuous governmental effort to systematise and consolidate teacher education programmes in Malaysia.

1.3.4. A Comprehensive Teacher Education Programme

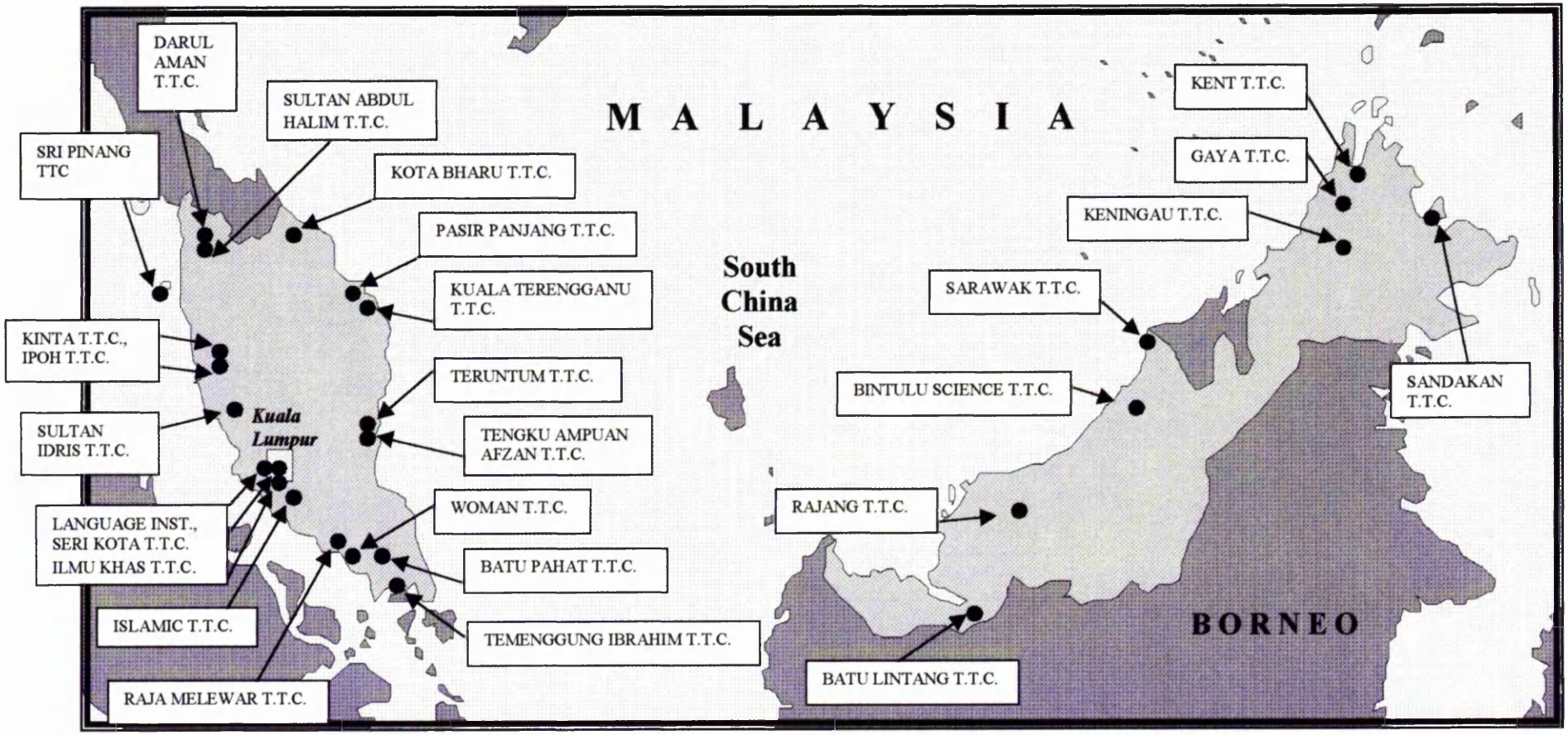
Currently, the Teacher Education Division of the Ministry of Education conducts college teacher education programmes in Malaysia through thirty-one teacher training colleges/institutions (see FIGURE 1.2). Since 1982, the implementation of a teacher education programme was guided by its mission statement:

> "**The Teacher**, who is noble in character, with progressive and scientific vision, is committed to uphold the aspirations of the nation, cherish the national cultural heritage, ensure the development of the **individual**, and preserve a united, democratic, progressive and disciplined **society**"
> (Ministry of Education, 1982; p.1)

In meeting the challenge of producing teachers as envisioned in its mission statement, the minimum academic qualification for the new teacher trainees had been raised from holders of the Malaysian Certificate of Education to holders of the Malaysian Higher Certificate of Education. In addition, candidates' co-curricular activities are also considered to be an important criterion for teacher trainees' admission selection. In parallel with the Malaysian government's policy of strengthening teacher education for nongraduate teachers, the teacher trainees have to pass two important aptitude tests prior to their acceptance into teacher training colleges. This is to assess candidates' scholastic abilities as well as predicting their future teaching performance and creativity (Marzuki *et al.*, 1994)

The duration of training is two and a half years for academic teachers, comprising four semesters of course work and a final semester of practical attachment in schools. For technical and vocational teachers the duration of training is three years, or six semesters, comprising four semesters for course work and a final two semesters of teaching practice in schools. Essentially, the curriculum of the teacher education

FIGURE 1.2
TEACHER TRAINING COLLEGES/INSTITUTES IN MALAYSIA



T.T.C. = Teacher Training College

programme may be seen as comprising four major components; basic courses, professional courses, teaching practice and self-development. Additionally, there are three major types of extra-curricular activities; activities of uniform teams or associations, clubs and societies and sports and games. The main aim of these activities is to equip the student teachers with expertise, skills, and competencies to implement extra- curricular activities at the school level. In 1990, in line with the Ministry of Education's policy of having only university graduate teachers in the secondary schools, the PostGraduate Teacher Education Programme was introduced.

1.4. THE GRADUATE TEACHER EDUCATION PROGRAMMES

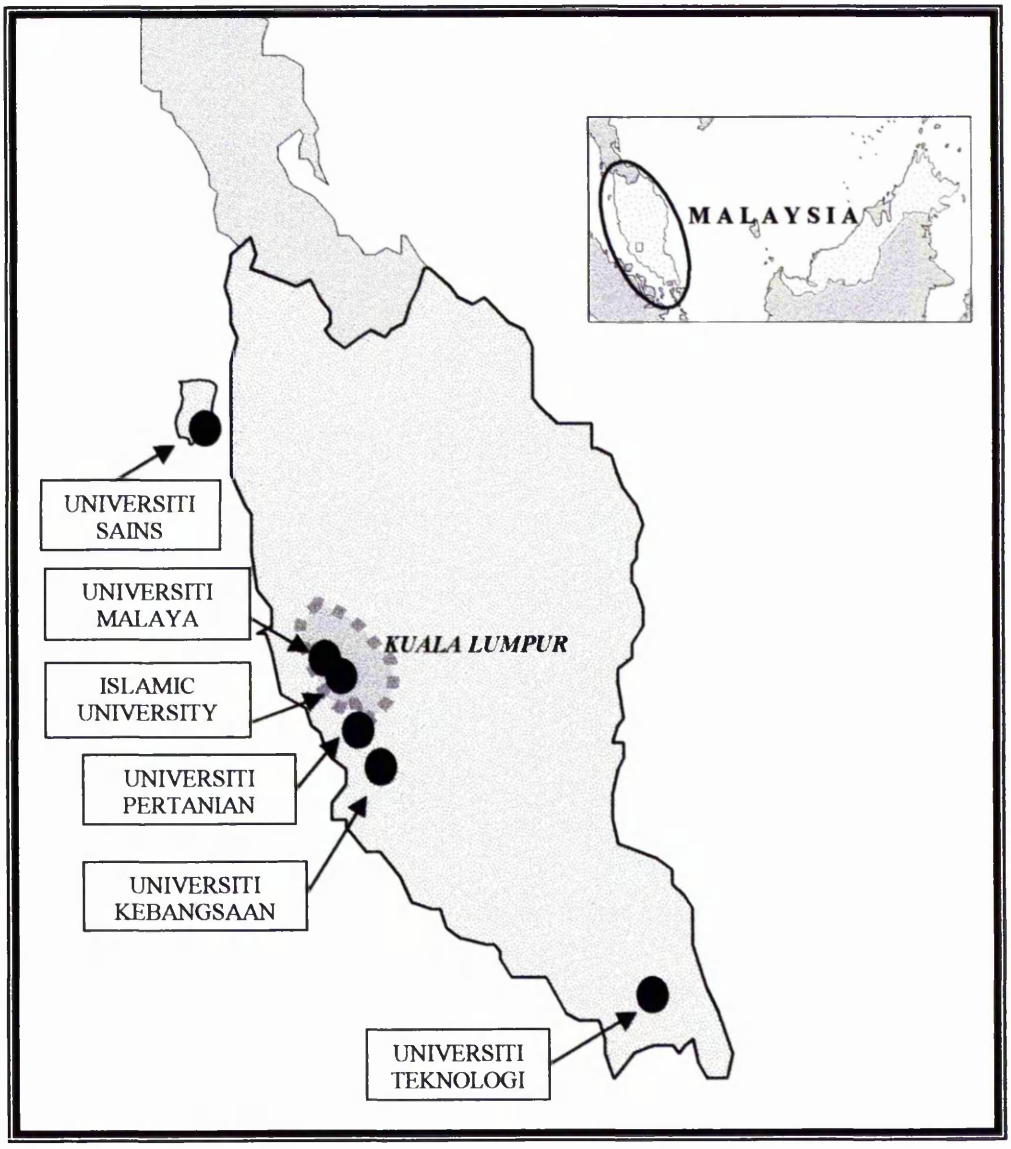
In the past three decades post colonial Malaysian politics, economics, social needs and the demands of a newly developing country has influenced the overall panorama of teacher education. In place of a multiplicity of teacher training schemes there exist today only two main co-ordinated programmes: one for training non-graduate teachers by the colleges of education and the other for training graduate teachers by the universities (see FIGURE 1.3).

It will be recalled (page 45) that early ventures into graduate teacher training only began when the Universiti Malaya set up its own School of Education in 1963. From the beginning, this Faculty embarked on a series of experiments in teacher education and became the main source of supply of graduate teachers for Malaysian secondary schools. An analysis of the enrolment calendar found that momentous changes have taken place within its ten years of operation. Starting from only 35 students in 1963, enrolment was increased to 621 in 1973. Students joining the programme came from various academic backgrounds covering Science, Social Sciences, and the Humanities (Hoy Kee and Phang, 1975).

Prior to 1971/1972, the teacher education curriculum was classified as "General" and "Specialised". The former encompassed Principles of Educational Practice and Invitational Lectures while the latter included Special Method and

FIGURE 1.3

UNIVERSITIES OFFERING GRADUATE TEACHER TRAINING PROGRAMME



Optional Courses. Since the academic background of students varied widely, special method courses by means of micro teaching were integrated into three cognate areas: Language Methods (Bahasa Melayu (Malay Language), English and Chinese), Science Methods (Physics, Chemistry, Biology, Mathematics, Agricultural Science, Engineering and Technology) and Social Studies Methods (Economics, Geography and History). Increases in student enrolment necessitated structural changes of the curriculum. Starting from 1972, compartmentalisation of courses into three distinct segments (Foundation of Education, Methodology of Teaching and Teaching Practice) was practised to ensure the efficiency of curriculum implementation. The former Principles of Educational Practice and Optional courses were combined under a new Foundation of Education course.

Until the early 1970*s*, the Universiti Malaya was the only supply of graduate teachers for Malaysian secondary schools. Later, the prototype programmes were replicated and graduate teachers were trained at five other newly established universities: the Universiti Sains Malaysia, the Universiti Kebangsaan Malaysia, the Universiti Pertanian Malaysia, and the Universiti Teknologi Malaysia. In the 1980*s*, the International Islamic University was established, which also has a school of Education (Noor, 1993).

1.4.1. Teacher Education Programmes in the 1970*s* and 1980*s*

The 1970*s* and 1980*s* manifested early emergence of newly designed teacher education programmes within a specifically Malaysian framework. The hidden agenda underpinning its implementation was a response towards the educational challenges delineated in the New Economic Policy and five-year massive governmental plan (see also page 31-32). Other than the sequential Diploma in Education, new programmes such as the Concurrent Diploma in Education, Bachelor of Science with Education, Bachelor of Arts with Education, Bachelor of Education and Bachelor of Islamic Education were introduced. Teacher training colleges also

moved a step forward by introducing Post-Graduate Courses in Education and Post-Graduate Certificate of Education in the 80*s*.

1.4.1.1. The Concurrent Diploma in Education

A unique three-year concurrent academic-cum-teacher education programme was introduced by the Universiti Kebangsaan Malaysia a year after its establishment in 1971. Essentially, students enrolled in the programme would accumulate the necessary units in education within the three-year normal academic sessions, thus equipping themselves with professional knowledge. Sequentially planned along a three-year continuum, this course offered wide opportunities for undergraduate students who wished to qualify at the Diploma in Education level while studying for academic degrees.

Although the programme was successful in achieving its ultimate aim (to produce graduate teachers at a faster rate), low quality enrolment, heavy student workload and administrative problems led to the termination of the programme in 1981. A new sequential diploma of education was later introduced to replace the then existing teacher education programme. Instead of spreading the courses over a three-year period, they were compressed into one year.

1.4.1.2. The Bachelor of Science with Education

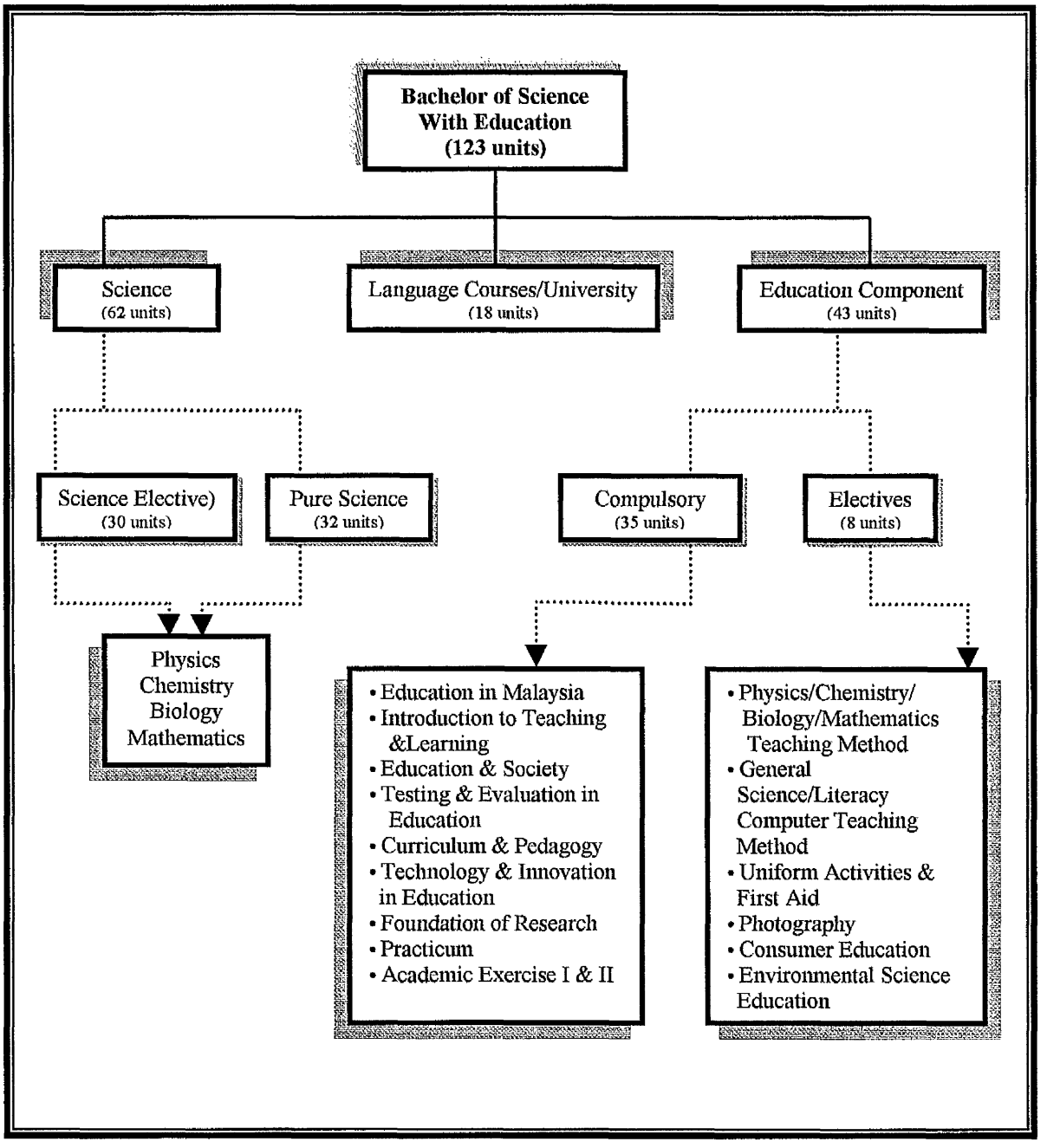
The four-year Bachelor of Science with Education programme was pioneered by the Universiti Sains Malaysia in 1970. It was an integrated teacher education programme where professional teaching courses were incorporated with science and mathematics courses. Achievement in both academic subjects and teaching professionalism would lead to the award of an honour degree in Science with Education. 66.7% of this programme comprised the academic component and the remainder the educational components including teaching practice. Such compartmentalisation was designed to ensure that teachers possess sufficient

theoretical background and teaching professionalism to teach Science and Mathematics not only at a secondary level, but also up to college level.

Student teachers were orientated to the Malaysian educational setting as well as the basics tenets of teaching practice in the first year. In the following year, courses exposed students to the three basic educational disciplines; Philosophy of Education, Educational Psychology and Sociology of Education as the precursor to the courses on the principles and practice of education, to which students were exposed at the end of the second year. Methodological and pedagogical knowledge in Science and Mathematics were introduced in the third year. The use of a wide range of instructional resource materials and teaching aids were also taught. Principles and practices of evaluation, educational guidance and counselling and health and physical education were also included. In the final year special attention is given to the teaching of Science and Mathematics. Further understanding of educational issues is enhanced by compulsory study of contemporary educational problems. A range of optional courses (e.g. curriculum development, educational planning and administration) provides advanced learning in educationally related courses. As a pre-requisite of graduating, students are required to conduct small-scale surveys or investigations on certain aspects of Science Education problems (for example mathematical ability as a predictor of physics achievement). Appreciation of music and art is also taught as a non-examinable course to introduce an aesthetics element into teacher training. Practical teaching, totalling sixteen weeks was spread over the first three years of the programme. The structural illustration of this programme as implemented at the Universiti Kebangsaan Malaysia is shown in FIGURE 1.4.

FIGURE 1.4

STRUCTURE OF THE BACHELOR OF SCIENCE WITH EDUCATION PROGRAMME (UNIVERSITI KEBANGSAAN MALAYSIA)



In 1973 the Universiti Malaya replicated the programme, and the Universiti Pertanian Malaysia followed two years later. In conjunction with the government's effort to increase the number of Science teachers, the Universiti Kebangsaan Malaysia also initiated the same programme in 1984 followed six years later by the University Teknologi Malaysia. A comparative analysis of the curriculum reveals that each university varied the educational and academic inputs, but the overall academic component consistently constituted some two thirds of the overall curriculum. The average ratio between the academic and education components is 1: 2. TABLE 1.4 summarises the programmes currently conducted by the universities.

TABLE 1.4

THE PROPORTION OF ACADEMIC AND EDUCATION COMPONENTS OF THE BACHELOR OF SCIENCE EDUCATION PROGRAMME

Institution	Components (%)			
	Academic	Education	Others*	TOTAL
Universiti Malaya	64.2	26.0	9.9	100.0
Universiti Kebangsaan Malaysia	50.4	35.0	14.6	100.0
Universiti Teknologi Malaysia	56.3	28.0	15.6	100.0
Universiti Sains Malaysia	52.9	47.1	-	100.0

* Language, University Compulsory Courses

1.4.1.3. The Bachelor of Arts with Education

The implementation of the Bachelor of Science with Education encouraged the Universiti Sains Malaysia to initiate a further series of teacher training innovations. From June 1973, Universiti Sains Malaysia has expanded its four-year concurrent academic-cum-teacher education programme to permit enrolment of students from the Schools of Humanities and Comparative Social Sciences. The ultimate aim is to produce competent language teachers (either Bahasa Melayu or

English) who are also capable of teaching history or geography. The resulting BA with Ed programme is similar in its nature to the BSc. with Ed. Programme, except that history or geography and Bahasa Melayu (Malay Language) and English take the place of Science subjects.

1.4.1.4. Bachelor of Education

In the late 1970*s*, the Universiti Pertanian Malaysia established its Bachelor of Education programme. Candidates enrolling in the programme came from a wide range of knowledge background from Agricultural Science, Home Science, Physical Education, Teaching of Bahasa Melayu (Malay Language) as a First Language, Teaching of English as a Second Language and Guidance and Counselling. The main feature of the programme was an emphasis on elective subjects such as Home Science, Agricultural Science and Physical Education, which are only offered at the college level. Ironically, the introduction of these new programmes increases enrolment from the college-trained teachers' cohort. The Bachelor of Education at the Universiti Pertanian Malaysia followed the same pattern as the Bachelor of Science with Education programme. Successful completion of 67% of academic courses, and 33% of educational courses leads to the conferment of the degree of education.

The recognition of the value of teaching professionalism brought about the expansion of the B.Ed programme. The Universiti Sains Malaysia also introduced the B.Ed programme to replace its concurrent academic-cum-teacher education programme. Unlike its predecessor, the new programme gives greater emphasis on the educational components. An equal balance between the academic and teaching professionalism courses was seen as important in producing a well-educated teacher to meet the challenges of the fast changing educational system in the 70*s*. Academically, the student teachers were expected to specialise in one subject (any science or arts subject). A foundation in teaching professionalism was encouraged through "educational foundation courses" (for example: Education in Malaysia and

Psychology of Learner and learner's Needs), "educational related advanced studies" (for example: Counselling Psychology). Before completing the programme, student teachers are required to conduct a simple survey or some school-based research. This provides them with an opportunity to understand and empirically explore the educational theory and practices learnt during the programme.

1.4.1.5. Bachelor of Islamic Education

The Universiti Malaya launched the Bachelor of Islamic Education in the 1980s. The aims of the programme were twofold; to establish a systematic professional training for religious teachers and to upgrade the standard of religious instruction especially in the secondary schools. Just like the other teacher-integrated programme, the training of religious teachers requires the student teachers to take some 70% Islamic related components and 30% professional educational components.

1.4.2. Teacher Education in the 1990*s*

Essentially, teachers are trained in line with the aspirations outlined in the National Philosophy of Education so that they are best able to meet the challenges of the Vision 2020. The extent to whether the new graduate teacher training programmes have been successful is still in question.

1.5. SUMMARY

The educational system in Malaysia has come a long way from being a diversified non-formal system to a unified formal and forward-looking system. This evolution has taken place within a complete historical and multi-racial context. At times the country's educational goals and objectives have been just a pale imitation of the British school curriculum. The Razak Report (1956) provided a turning point in the history of the Malaysian educational system. Its recommendations became the

catalyst to a comprehensive system of education designed to meet the current and future demands of a developing country where the overriding concern was to create a unified education for all people regardless of race and creed.

Once unity among the population had been attained, and democratisation of education established, the next function of reform was to meet the demands of a newly independent country. As the nation progressed scientifically and technologically, there came a need to expand the Vocational and Technical education of the children. Recognising a deficiency in the numbers of Science and Mathematics teachers, the Bachelor of Science with Education programme was inaugurated by the Universiti Sains Malaysia in 1970. This programme was later followed by other universities across the country.

A second turning point in the educational system occurred in the 80*s* through the inception of the National Philosophy of Education, which stressed the importance of well-balanced citizens capable of contributing to the betterment of the country. New educational reform followed, the most significant of which was the integration of moral values across the curriculum that symbolised the re-emergence of Islamic influence across the curriculum. In 1993, five years after the implementation of the National Philosophy of Education, the third turning point occurred when the Prime Minister introduced his Vision 2020 plan which was designed to lead Malaysia to be a fully developed nation by the year 2020. The drive to be innovative and forward looking, and to be a contributor to scientific and technological advancement led to a curriculum which emphasised the shift towards the development of human capital equipped with critical and creative thinking capacities (see page 35). The analysis of the current Science teacher education programme (FIGURE 1.4, page 54) fails to indicate any reference to the importance of critical thinking. If teachers are seen by the government to be vital in delivering reform (see page 23), then they must have the necessary professional knowledge, understanding and skills to be able to do so. This is the point of departure for this thesis; how to inculcate in new members of the

profession appropriate critical thinking capabilities, and how these are to be passed to the next generation of Malaysian citizens in order to fulfil the goals of Vision 2020.

2

CONTEXT OF THE PROBLEMS

2.1. INTRODUCTION

In Malaysia, the changes in education do not seem to occur at the same rate as other areas of development. Perhaps, the root of this problem is the failure of the public institutions, and just as importantly the teachers, to upgrade teaching to an appropriate level of professionalism. This chapter will identify and discuss some of the contributing factors which impede the efficiency of the educational changes that are required to achieve the objectives of Vision 2020. It will also explore the issue of inculcating critical thinking skills into the teacher training curriculum as being part of the solution of eliminating the concept of education being merely a transmission of knowledge. During the course of this chapter, the underlying validity of including critical thinking skills in teaching methodologies especially in the field of science education will be examined through reference to literature on critical thinking skills.

2.2. CHALLENGES TO TEACHER PROFESSIONALISM IN MALAYSIA

Currently, teacher education in Malaysia could be portrayed as being still in a state of flux. It is thus not surprising that no teacher comes out of the teacher-training programme as a "full-fledged" teacher. He/she may have the necessary pre-requisite knowledge and skills, but the repertoire of teaching techniques can never really be said to be complete. Studies have indicated that pattern the of instruction teachers employ in the classroom is shaped during the training programmes. For instance Gallagher (1967) wrote that most teachers teach as they were taught (cited in Yeanny and Padilla, 1986). Similarly, Yeany and Padilla (1986) in their synthesis of research findings from several teacher training practices (e.g. Harris, Lee and Pigge, 1979; Lange, 1971; Riley, 1979), concur that patterns of teachers' instructional techniques are direct manifestations of the modelling teaching strategies to which they were exposed during their training programmes. More recently, Johnson (1994) has concluded similarly.

Traditionally, teaching as a profession is often characterised as having a specialised knowledge base and shared technical culture of teaching (Caldwell, 1997; Hargreaves and Goodson, 1996; Talbert and McLaughlin, 1996). Thus, "professionalism" focuses on the question of what qualifications and acquired capacities, what competence, is required for the successful exercise of teaching. "Professionalisation", on the other hand "relates to the authority and status of the teaching profession" (Englund, 1996; p. 76). Presumably, it is a manifestation of the historical and social ambition of the occupational group to achieve status and position in society and hence is a measure of the societal strength and authority of the occupational group (Hargreaves and Goodson, 1996). In this sense, both professionalisation and teacher professionalism should be important elements in the shaping of teacher education programmes (McLaughlin, 1997; Helsby and McCulloch, 1996). The lack of teacher training programmes in modelling teacher behaviours in the classroom coupled with lack of congruence in terms of duration of training and curricular and extra-curricula implementation between universities and college teacher education programmes have resulted in Robiah (1994) arguing that teacher training in Malaysia has not reached an appropriate level of professionalism. Factors that impede the professionalisation of the teaching profession in Malaysia, include the lack of studies on teachers' beliefs and attitudes as well as the continuing professional development of teachers. The situation is aggravated by a deficiency in relevant research on teacher education and the declining status of teachers (Lourdusamy and Tan, 1992; Salleh, 1993; Konting, 1995).

2.2.1. Studies on Teachers' Beliefs and Attitudes towards Teaching

Learning from cognitive point of view is an active and constructive process that is strongly influenced by an individual's existing understandings, beliefs, and preconceptions (Resnick and Klopfer, 1989). It is almost a truism that student teachers come to teacher education programmes with strong personal theories of teaching (Brookhart and Freeman, 1992) and a model of the teacher which have been well established from their school experiences (Clark and Peterson, 1986; Nespor,

1987; Weinstein, 1989), itself rooted from childhood experiences and culture (Bullough, 1991; Clandinin and Connelly, 1987; Weber and Mitchell, 1996) . Critical examinations of attitudes and beliefs of pre-service student teachers found that existing knowledge and beliefs play an important role in determining how student teachers approach their teacher education programmes (Book and Freeman, 1986; Calderhead and Robson, 1991; Clark, 1988; Nespor, 1987; Sugrue, 1996).

Richardson (1996), argued that attitudes and beliefs are important in comprehending teachers' thought processes, classroom practice, and learning to teach; such thoughts and beliefs of teachers play a significant role in guiding their instructional practice (Clark and Peterson, 1986; Hasan and Bileh, 1975; Lucas and Dooley, 1982; Shrigley, 1978) as well as influencing the teacher change process (Nespor, 1987; Pajares, 1992). Since teachers' attitudes and beliefs determine their classroom practice, the design of teacher education programmes should take the concept of changing attitudes seriously into account.

In Malaysia, the study on teachers' beliefs and attitudes should become the main agenda since as argued by Noor Azmi (1988), negative attitudes and perceptions of curriculum key players (i.e. the teachers) are the main reason which caused the failure of the new curriculum implementation. Although recently there have been empirical studies on the effect of teachers' beliefs and attitudes on their instructional practice (e.g. Konting, 1995), no attempt has yet been made to challenge and change those beliefs and attitudes. Malaysia has called for teacher educators to identify the kind of professional knowledge, skills and values needed to prepare teachers adequately to enact the changes of the new vision of schooling it has. For "what teachers think, what teachers believe and what teachers do at the level of the classroom ultimately shape the kind of learning that young people get" (Hargreaves and Fullan, 1992; p.ix).

2.2.2. Lack of Continuing Professional Development of Teachers

The lack of specific objectives for teacher training programme in Malaysia has resulted in them failing to equip teachers with higher order cognitive competencies necessary for encountering daily classroom problems. In 1983, studies were conducted to measure the effectiveness of a newly introduced comprehensive teacher education programme at the college level (ASEAN, 1983). Assessment of its Foundation/Professional courses found that few subject or course activities were relevant to the holistic development of teachers engaged in philosophy of teacher education programme (see page 47). In most cases, teachers always presumed themselves as professionally qualified and adroit in handling teaching and learning tasks upon completion of their courses. However, with respect to university teacher graduates, Salleh (1993) also detected that many had problems; especially in their knowledge of the second subjects they teach and in instructional skills, which tended to be rooted in only a shallow understanding of the knowledge of curriculum and educational policy.

2.2.3. The Deficiency in Relevant Research on Teacher Education

There is also a lack of relevant research on teacher education, especially that directly related to the actual teaching and learning in the Malaysian context. Studies so far are eclectic and discrete, distributed over widely different subjects areas and do not provide comprehensive guidelines for educators for developing teacher education (Khoo, 1979: Leavitt, 1991; Sim, 1991) programmes that are well-suited for teacher trainees in Malaysia. The call for a rationalised national teacher education research programme is crucial, not merely due to the unique character of its multi-pluralist society, but because Malaysia herself has stressed the need for development not only in terms of economic and socio-political stability, but also spiritually, psychologically and culturally (Khoo, 1979)

2.2.4. The Declining Status of Teachers

For many in Malaysia, like the United Kingdom (Eggleston, 1992) and the United States of America (Gitlin and Labaree, 1996), teaching is often regarded as not the first choice of career or profession. Many, especially those assigned to teach English and Science (particularly in the Diploma of Education Programme) are not actually trained to teach their subjects. The consequences of teachers' perceived marginal professional status are significant. In conjunction with the implementation of the Integrated Primary School Curriculum (IPSC) studies by the Universiti Sains Malaysia (1987) detected that many of the teachers failed to manifest appropriate teaching and learning strategies in real classroom events (Robiah, 1994). Inspectorate studies (1990) show only 45 percent of teaching staff displaying strong commitment to school goals and even less show interest and deep commitment in professional development by reading educational journals and books. Although 60% of them have been identified as being able to teach effectively, this still leaves a sizeable minority maintaining traditional methods of teaching; viz. didactic, teacher-centred and chalk-and-talk methods. Similarly, Lourdusamy and Ghani (1990) report that the vast majority of student teachers enrolled in the Bachelor of Arts and Bachelor of Science programmes viewed teaching activities as neither enjoyable nor creative endeavours. Even worse, more than 15% of the student teachers perceived teaching "as static, conservative, confirming, passive, disorganised and stereotyped in nature" (cited in West, Jarchow and Quisenberry, 1996; p. 1074)

What emerges from this brief outline of teacher education in Malaysia, is that of a lack of knowledge of the effect of teachers' attitudes and beliefs. Thus, in the quest of upgrading teacher professionalism in Malaysia, the professionalisation processes must concentrate towards the development of teachers' attitudes and beliefs and how to challenge and change those attitudes during their learning experiences as student teachers. It is argued that attitude changes would in turn, lead to the subsequent changes not only in their professional knowledge about teaching, but also their actual teaching behaviours.

2.3. CALLS FOR THE INCULCATION OF CRITICAL THINKING SKILLS IN SCIENCE EDUCATION

The combination of declining test scores, the increase of information and technology and fast-paced changes in society caused by the latter (Hunt, 1995) have focused increased attention on the need to do more than merely transmit an abundance of information to the children (Maina, 1997). The role of educators is shifting towards providing means by which children develop skills in thinking and therefore, in ways of using information to produce individuals who are capable of thinking new thoughts, instead of repeating what others have thought. This kind of transformation is described by Wolf *et al.* (1991) as a shift from the *epistemology of intelligence* to the *epistemology of mind.* It is a new emphasis on the process of thinking that is being witnessed (Butler, 1993).

It is also a truism, in an age when information can be attained almost instantly at our fingertips, via the Internet and other remote services, that the memory need no longer be seen as the most important of intellectual skills. More appropriate is that learners learn how to utilise the data available to them (Kaplan, 1997), they need the ability to think intelligently about the issues confronting them.

It is therefore argued that school programmes should be attending systematically to improving the thinking skills of their students. The prime reason is that adroitness in thinking does not develop on its own. It is clear from the literature that effective, skilful thinking is neither a natural individual outcome of experiences nor an automatic product of study in any particular subject area (Mayer, 1983; Glaser, 1984; Bransford *et al.*, 1986; Beyer, 1987; 1988; Blagg *et al.*, 1988; Pizzini *et al.*, 1988; 1989; Cameron, 1989; Swartz and Perkin, 1989; Newmann, 1990). It requires deliberate, continuing instruction, guidance and practice in order to develop to its fullest potential, and it follows that schools must offer appropriate settings and expertise in instruction so that individuals are enabled to develop thinking proficiency.

Unlike factual skills which tend to be forgotten once the student leaves the classroom (Gustav, 1969; Blunt and Blizard, 1975) the skill of thinking will never be outdated (Quinby, 1985). On the contrary, such skills enable learners to acquire knowledge and to reason with it, regardless of the time or place or the kind of knowledge to which it is applied. Thus, thinking skills are often perceived as a survival skill for society as a whole as well as for individuals (Beyer, 1988a, 1991; Swartz and Perkins, 1989; Newmann, 1990; Micheal 1991). The contribution made by such learning to the well being of society will help a country to keep abreast of global technological advancement.

With respect to science education, many educators have indicated that teaching students to apply scientific knowledge so that thinking and problem solving skills can be nurtured and cultivated should be a significant goal of science instruction (George, 1967; Champagne and Klopfer, 1977, 1981; Bass, 1981; Chiappetta and Russell 1982; Pizzini *et al.*, 1988, 1989; Harty, Kloosterman, and Matkin, 1991; Bentley and Watts, 1992; Devender, 1992; Ziedler, Lederman, and Taylor, 1992; Zohar and Tamir, 1993; Kuhn, 1993). In fact, the development of thinking and problem solving skills has been regarded since ancient times as one of the major aims of science education (Resnick, 1987; Blagg *et al.*, 1988). Thus, science educators must continually strive to create a conducive learning environment that enhances critical thinking and problem solving skills. Such an environment will depend upon more than the physical conditions of the classroom (Newmann, 1990). Science teachers must value thinking, provide time for it, support it and evaluate its growth. It is for teachers to create the environment that will encourage active student participation; i.e. students must be a *part* of the science environment, not *apart* from it (Pizzini *et al.*, 1988).

Despite the recognition of the importance of thinking and problem solving skills in the literature, the most dominant theme in recent science education research literature suggests that even the very best students master little more than the regurgitation of rote learned knowledge (Pizzini *et al.*, 1988). Science teachers all

over the globe are commonly under pressure to teach facts and cover all the topics included in the syllabus within the assigned time rather than develop student thinking (Tobin *et al.*, 1988; Osborne and Freyberg, 1985; Pizzini *et al.*, 1988). In a study of 11 high school science classes, Mitman *et al.* (1984), it was found that a very low portion of academic tasks required students to use the higher order cognitive skills outlined in Bloom's Taxonomy (e.g. synthesis and evaluation). Most of the assessment tasks only required students to use lower level cognitive operations (e.g. knowledge and comprehension). It was also found that this situation was exacerbated by a tendency for teachers to grade worksheets and laboratory reports for completion rather than accuracy. On occasions when teachers have endeavoured to emphasise higher cognitive level outcomes, barriers to higher level learning were created. Stanford (1985), for example, describes a situation where science teachers and students interacted to actually reduce the cognitive demand of academic tasks. For instance, students segregated in a small group copied from one another, and in open book tests, they were able to copy information that previously has been copied from another source (e.g. chalkboard or another student's work).

Additionally, teachers also used the "safety net" (e.g. assigning more marks to memory or procedural components of a task; allowing students to revise products after they have submitted them; grading on completion rather than accuracy; using easy or familiar content on tests) in much of their classroom activities (Tobin *et al.*, 1988). Such instructional approaches fail to challenge students to use their minds in other ways, to develop problem-solving skills to relate the importance of problem solving to science. All in all, Newmann (1990) concludes that much of the activity in a science classroom can be considered as "nonsensical" or "mindless".

The scenario of science education in Malaysia is unlikely to be much different from this overall picture (Phillip, 1992). For instance Kassim (1989) describes generally the preferred styles of science teaching as "fact-giving balanced with problem solving activities, using didactic and teacher dominated events" (p. 199). Similarly, Sharifah Nor (1994) describes:

> "...the teaching and learning studies in science classes was very "teacher-centred" with a high degree of teacher dominance in the learning process. ...In all instances the teacher was the giver, imparter of knowledge and information as well as the centres of learning activities rather than working with the students. Any attempt to involve student actively in the learning process seemed to be limited to doing experiments and answering questions either individually or in chorus. Even though, students were involved in doing experiments, most of the time these were done after the teacher had told them about the observations and results of the experiments. In many of the classes observed, teachers not only gave the results of the experiments, but also wrote or dictated the reports which students copied into their notebooks"
>
> (Sharifah Nor, 1994; p. 262)

Yet, it will be argued that in Malaysian society a problem solving approach to the teaching of science is more important than in more advanced countries, and specific instruction involving students thinking should be an integral component of the Malaysian science education curriculum.

2.4. JUSTIFICATION OF CRITICAL THINKING AS AN EDUCATIONAL IDEAL IN MALAYSIAN SCIENCE EDUCATION PROGRAMMES

As empirically demonstrated, there is a tendency for teaching methodologies currently used by teachers in Malaysia to result in pupils who know facts without understanding them (Kassim, 1989; Sharifah Nor, 1994). The traditional Malaysian educational process trains pupils to be rote learners but not thinking beings. Such individuals can perform routine tasks but are insufficiently innovative and creative. In short, their education has thus far failed to actualise the potential envisaged in the Philosophy of Education and mission statement of Vision 2020.

However, the aims, objectives and emphases of the Integrated Secondary School Science Curriculum (ISSSC) programmes are designed to promote "a scientific way of thinking", "a scientific approach to problem solving", "desirable attitudes towards science" and "an awareness of the importance of science in human affairs". In terms of content organisation, the ISSSC stresses "humanising in the science curriculum". Based upon this concept, science is defined as a "set of disciplines of knowledge, which is an outcome of man's effort to seek out rational

explanations for various natural phenomena occurring around him". Therefore, the expected product of the ISSSC programme is an "individual who is the mortal benefactor of the universe, who has been entrusted to manage the universe and its resources in a responsible manner". In order to achieve such aims, individuals need to be trained as thinking beings who can be educated to make appropriate life decisions which in turn, enable them to contribute to democratic society. Besides empirically proven as a predictor of students' academic achievement across subject knowledge (Worsham and Austin, 1983; Crow and Haws, 1985; Collin, 1991; Zohar, Weinberger, and Tamir, 1994; Hill, 1995; Gambino, 1995; Moore, 1995; Duffy, 1996; Hall, 1996; Stewart, 1997), critical thinking plays a vital role in providing the means by which the aims and objectives of the ISSSC may be realised.

The first reason for perceiving critical thinking as a worthy educational ideal is to do with education's generally recognised task of equipping students with all the necessary abilities for the successful management of adult life. As teachers, it is our responsibility to bring students as quickly as possible to the point at which they can "take over reins" and guide their own education and life generally. That is, teachers must strive to render the child self-sufficient by empowering the students to control their destiny and to create their future, not submit to it (Scheffler, 1973; Giroux, 1983). To get the students to the point, where they can control their own lives and responsibly contribute to social life is to bring the students into the adult community, to recognise the students as fellow members of a community of equals. As suggested by Scheffler (1973) and Siegel (1988), the best means of empowering the students is by inculcating appropriate attitudes to, and skills in, critical thinking. By encouraging critical thinking, students are trained to become independent and competent judges and so to make judgements regarding the appropriateness of alternative beliefs, courses of action and attitudes on the basis of rational thought. Such individuals are more likely to be free of unwarranted beliefs and insupportable attitudes.

Besides inspiring the students to a commitment of their social responsibilities, critical thinking is strongly associated with personal and moral development

(Lutwak, 1984; Loevinger, 1976). Lutwak (1984) in an exploratory study seeking the inter-relationship between ego, moral and conceptual development found that the key element connecting these three variables is critical thinking ability. In a similar vein, Loevinger (1976) found that aspects of critical thinking (for instance: self-awareness and an appreciation of multiple possibilities in situations) are necessary for ego, moral and conceptual development. Further evidence of the inter-relationship between critical thinking and personal and moral development, has been empirically demonstrated by Hill (1995). Hill showed that the critical thinking skills of induction and deduction, exploring alternatives, and decision making were essential for personal and moral growth.

It is also suggested that one can learn to evaluate reasons by being initiated into the traditions in which reason plays a role. In the context of science education, for instance, science students must learn, among other things, what count as good reasons for and against a particular hypothesis, theory, or procedure. They need practice in deciding rationally how much significance needs to be taken of particular explanations. Rationality plays a crucial role in this. As a social activity, science advances through thought processes that occur between persons, not just within them (Westrum, 1989). There can, however, be no scientific method that is capable of detaching science from controversy and argument (Ziedler *et al.*, 1992). Kuhn (1993) also stresses that scientific facts and theories are argumentative constructions that need to be debated. Thus, critical thinking, it is claimed, helps students to understand and appreciate the role of reason in rational endeavour, and of fostering those traits that encourage the seeking of reason for the grounding of judgement, belief and action.

As a democratic country, Malaysia needs citizens who are factually well-informed, who grasp fully the nature of democratic institutions and who embrace democratic responsibilities; for example in treating fellow democrats as equal partners in life. Part of the responsibilities of a democrat is to protect and ensure the confirmation of the democratic way of life and this means an ability to examine

public policy concerns, to judge intelligently the many issues facing society, to challenge and seek reasons for proposed changes (and continuation) of policy; to assess such reasons fairly and impartially, and to put aside self-interest when it is appropriate to do so (Siegel, 1988). Glaser (1984) suggested that critical thinking ability can "help the citizen to form intelligent judgement on public issues and thus contribute democratically to the solution of social problems" and Postman (1985) argued that there can be no liberty for a community that lacks critical skills to distinguish lies from truth. The relationship between critical thinking and democracy as advocated by Scheffler (1973) is a very close one. Ideally democracy aims:

> "...to structure the arrangements of society as to rest them ultimately upon the freely given consent of its members. Such an aim requires the institutionalisation of reasoned procedures for the critical and public review of policy; it demands that judgements of policy be viewed not as the fixed privilege of any class or elite but as the common task of all, and it requires the supplanting of arbitrary and violent alteration of policy with institutionally channelled change ordered by reason persuasion and informed consent"
>
> (Scheffler, 1973; p. 137)

Therefore, it can be concluded that insofar as Malaysia is committed to democracy, critical thinking is a vital attribute, a central task of education in general, and science education in particular in producing what Plato called an "informed citizenry".

2.5 REBUILDING TEACHER PROFESSIONALISM: A NEW PARADIGM FOR SCIENCE EDUCATION AND INSTRUCTION

Teaching is "a profession with an undeveloped technical culture characterised by uncertainty about its process as well as outcomes" (Carlgren and Lindblad, 1991; p. 59). In order to reduce the uncertainties accompanying teaching activities, certain beliefs, knowledge and skills are required. With respect to the challenge of equipping science teachers with sound pedagogical content knowledge of how to inculcate students' critical thinking skills during their science instruction, it would appear axiomatic that the teachers themselves be skilled in this respect.

Attitude is defined by Allport (1967) as a predisposition that consistently affects actions. It is "a mental and neutral state of readiness, organised through

experience, exerting directive or dynamic influence upon the individual's response to all objects and situations with which it is related" (Allport, 1967; p. 8). Rokeach's (1968) definitions of attitudes include the concept of beliefs. Accordingly, for Rokeach (1968) an attitude set is "a relatively enduring organisation of beliefs around an object or situations predisposing one to respond in some preferential manner" (p. 112). Each belief within an attitude organisation is conceived by many as having three components which are closely inter-related (Eagley and Chaiken, 1993; Pajares, 1992). These components are *cognitive* components, which represent a person's knowledge, an *affective* component, because under suitable circumstances the belief is capable of arousing affects of varying intensity, and *conative* or *behavioural* components, because the belief, must lead to some action (Rokeach, 1968). The age-old trilogy of *affective*, *cognitive* and *conative* is also significant in Fishbein and Ajzen (1975) work.

Although some psychologists try to separate the concept of affective (attitude) and cognitive (beliefs) (e.g. Fishbein and Ajzen, 1975), the difference between the two terms remains unclear in the empirical literature (Richardson, 1996). For example, Harvey *et al.*, (1968) concluded that beliefs, as constructs, resembled attitudes. And Pajares (1992) regards beliefs, attitudes and values coming from the same belief system. Since, critical thinking disposition is an attitude, a commitment, and a tendency, it is therefore argued that it is an element of teachers' total system of beliefs.

Personal teaching efficacy which derived from Bandura's concept of outcome expectations and efficacy expectation (Bandura, 1977; 1982; 1989) refers to teachers' beliefs that they have the competence and skills to bring about student learning (Gibson and Dembo, 1984). Therefore, it could be argued that the beliefs teachers have dictate their perceptions and judgements, which, in turn, affect their behaviour in the classroom. Evidence from the literature on personal teaching efficacy shows a significant, positive relationship between student achievements (e.g. Brookover *et al.,* 1978), student motivation (e.g. Bandura and Cervone, 1983; Woolfork and Hoy,

1990), teaching commitment (e.g. Coladarci, 1992), teachers' classroom management strategies (Ashton and Webb, 1986; Guskey, 1988) and even teacher's openness to innovation (Guskey, 1988). Thus, it could be argued that a deeper understanding of the beliefs structures of teachers, and teacher candidates is essential in improving teacher professionalisation (Ashton, 1992; Brookhart and Freeman, 1992; Buchman, 1987; Munby, 1982; 1984; Nespor, 1987).

Besides beliefs, teachers require a body of professional knowledge to teach effectively. Shulman (1987) argues that there are three cardinal virtues of effective teaching: content knowledge, pedagogical knowledge, and pedagogical content knowledge. Content knowledge refers to teachers' knowledge of subject matter; pedagogical knowledge relates to teachers' general instructional knowledge; and pedagogical content knowledge covers teachers' knowledge of specific strategies for a particular subject matter. While content knowledge stands as a core of teachers' base for instruction, pedagogical content knowledge may be the most difficult aspect of teaching. Its acquisition will enable practicing teachers to make connections between their knowledge of pedagogy and their knowledge of content, connections which it is widely agreed are critical for teaching adroitness. Certainly, this is the type of professional knowledge that is especially important for teaching complex-thinking skills in a specific domain (Roehler *et al.*, 1988). Thus, its possession, it is claimed, is one key that distinguishes experts from novices in the classroom (Feiman-Nemser and Buchmann, 1986; Borko and Livingston, 1989; Borko, Bellamy, and Sanders, 1992). By explicating this knowledge, it is argued, one can turn teachers' intuitive, practical know-how and technique into visible, codifiable, professional knowledge. The recognition of pedagogical content knowledge as essential element in the studies of teachers' knowledge is evidenced in recent study of teachers' knowledge (e.g. Grossman and Richert, 1988; Omrod and Cole, 1996).

It could be argued therefore, the types of professional knowledge that contribute to effective critical thinking instruction are content knowledge about critical thinking and pedagogical content knowledge about critical thinking. The

former involves among all teachers' understanding of the core definition of critical thinking and the factors that influence students' learning of critical thinking. The latter on the other hand encompasses teachers' knowledge of available materials and resources for teaching critical thinking and effective pedagogies for imparting critical thinking skills in the classroom. Since content knowledge is inextricable from pedagogical content knowledge, the effectiveness of critical thinking instruction relies heavily on teachers' ability to integrate and adapt existing knowledge to students with varied levels of pre-requisite knowledge, critical thinking dispositions and critical thinking skills. Nevertheless, the art of combining these two types of knowledge is subtle, and requires a lot of experience as well as a great amount of reflective thought. Teachers' ability to integrate and apply the combination of these two types of knowledge is therefore argued as central to their effective critical thinking instruction.

In addition to beliefs and knowledge, teachers require various abilities to bring about student learning of critical thinking. As Hoelscher (1984) suggests, "if a teacher is to be an effective guide for the learning of problem solving skills, he or she must be an effective problem solver" (p.3). The abilities that characterise an effective teacher in critical thinking instruction would include thinking critically, inquiring skilfully, using materials creatively, applying teaching strategies appropriately, and employing meta-cognitive skills (Michelli *et al.*, 1990). FIGURE 2.1, proposed by Yeh (1996) displays a model of instruction in critical thinking as well as the relationship between an effective teacher and good critical thinker.

2.6. AIMS AND OBJECTIVES WITHIN THE CONTEXT OF THE PROBLEM

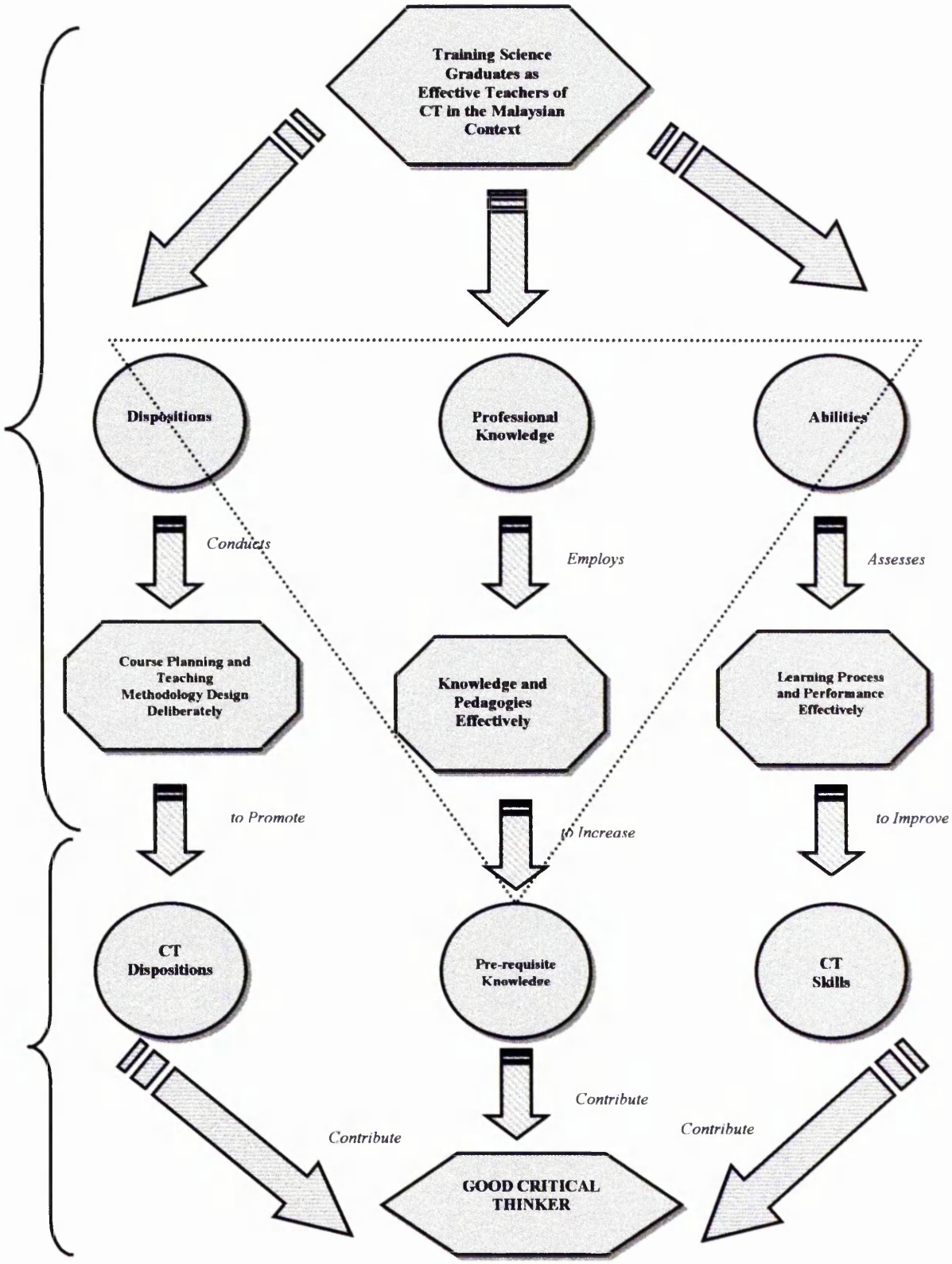
As depicted in FIGURE 2.1. successful critical thinking instruction is based on the teachers' attitudes, professional knowledge and abilities related to critical thinking. The possession of these three elements would in turn increase personal teaching efficacy in inculcating the teaching of critical thinking in their classroom

instruction; viz. through planning courses appropriately, employing knowledge and pedagogies effectively, and assessing students' learning processes and performance appropriately, teachers can, hopefully, improve the pre-requisite knowledge, critical thinking dispositions and skills in their students.

This study is designed to explore the effectiveness of teacher training in critical thinking instruction in changing teacher's *affective*, *cognitive* and *behavioural* responses. Specifically, it seeks to explore: (a) the effectiveness of intervention strategies in changing pre-service teachers' *dispositions* towards critical thinking, (b) their level of *professional knowledge* and *understanding* of the significance of critical thinking in science teaching, and (c) their *teaching behaviours* concerning the instruction of critical thinking. Stemming from these three objectives, this study seeks to make suggestions for effective training of pre-service teachers in critical thinking instruction. Accordingly, the following question is central to this study: Will exposure to teach critical thinking in science lessons through intervention strategies significantly change their *attitudes/dispositions* towards critical thinking, enhance their *professional knowledge* and so increase their *teaching behaviour* with respect to critical thinking?

FIGURE 2.1

RELATIONSHIP BETWEEN EFFECTIVE TEACHER AND GOOD CRITICAL THINKER



3

REVIEW OF RELATED LITERATURE

3.1. INTRODUCTION

The definition of critical thinking has evolved throughout the last half of the century. Though there is an abundance of educational, philosophical and psychological publications available in the critical thinking literature, it is appropriate to confine the discussion to a few major theories that bear on this research. Metacognition in itself is not a linear process, but rather recursive, particularly on issues which are mutually influential and the inter-relatedness of the theories upon one another is unavoidable. Analytical comparisons of the selected theories reveal that Ennis's work on critical thinking appears to be the most appropriate one that best fits the researcher's interest based within the framework of Malaysia's Integrated Secondary School Curriculum (ISSC) and its aims and objectives. An elaboration of Ennis's conception of critical thinking is carried out to provide the means for a more reliable discussion in selecting the appropriate teaching approach. It is the researcher's opinion that student teachers should be properly equipped before they embark into the realm of the real teaching environment.

3.2. THE CONCEPTION AND DEFINITION OF CRITICAL THINKING

The influence of Dewey's classical work, *How We Think* (1933) is reflected in most of the critical thinking literature. In the earlier part of his work, Dewey (1916) seminally defined the essence of critical thinking as "suspended judgement", or "healthy scepticism" (Dewey, 1933; p.125). For Dewey, bestowed memory provides us a stock of memory for future use. But judgement selects and adapts the memory to be used in an emergency. However, such judgement must be used when evidence sufficient to warrant its acceptance can be presented. This is that the concept of "reflective thought" appears within Dewey's definition. The execution of reflective thinking operations demand "active intellectual participation" (p. 9) which according to Dewey, helps learners intelligently integrate learning and experience. Thus, for Dewey, reflective thoughts entail "active, persistent, and careful

consideration of any belief or supposed form of knowledge in the light of the ground that supports it and the further conclusion to which it tends" (Dewey, 1933; p. 9). Zeidler *et al.* (1992) argues that such reflective thought reveal itself in a willingness to sustain a protracted state of doubt that may be aimed at any assertion or idea presented for acceptance. Critical thinking requires certain attitudes such as open-mindedness, and responsibility on the part of the thinker.

Later Dewey suggests a five–step dynamic process is involved in reflective thinking, and that each of these stages is essential to the process: identify a problem; analyse a problem; suggest possible solutions; test the consequences and judge the selected solution. Such a digest of critical thinking activities is reminiscent of the practice of problem solving (Mahan, 1967; Pizzini *et al.*, 1989). Dewey consistently reiterated that reflective thinking can only take place when there is an awareness that a problem exists and uncertainties about a solution are the basis of that awareness. Problem solving in the Deweyian sense is inherently interdisciplinary since it attaches to the real world where single definitive solutions are not easily attainable and all the relevant information may not be available. Although evidence, expert opinions and reasons could be brought to bear on the problem, no amount of reasoning and verification could guarantee any solution (Kitchener, 1983; Gallagher and Stepien, 1995).

To put it another way, critical thinking is a creative problem solving operation where intelligence acts upon experience (de Bono, 1990; 1991a; 1991b; 1993; 1995; 1996). This intentionally and consecutive ordering of thoughts is a premise of Dewey's which explains his association with scientific method and the inquiry mode of learning (Kitchener, 1983). It is the researcher's opinion that this is the most significant work in the field of critical thinking instruction and marks the birth of the inquiry mode of learning and which today provides frame of reference for cognitive theorists.

Glaser's (1941) prime contribution to the conceptual development of critical thinking was his direct involvement in the development of one of the comprehensive tests of critical thinking popularly known as the *Watson Glaser Critical Thinking Appraisal Test* (1980). Although this test employed the inventory of critical thinking skills developed by Dressel and Mayhew (1954), by 1941 Glaser had already produced his own definition of critical thinking; for him it was a three-faceted enterprise comprising attitudes, knowledge and skills. According to Glaser attitudes are important because they inspire persistence in the quest to examine any belief or supposed form of knowledge in the light of evidence that supports it and the conclusions to which it tends. But knowledge of the methods of logical enquiry and reasoning, and skills in applying those methods (including problem solving skills, information gathering skills, language skills, scientific method skills, judgement and generalisation skills) would also be needed in the development of critical thinking skills.

A more dynamic model of critical thinking is based upon Ennis's (1962) concept of critical thinking as "the correct assessing of statements". D'Angelo (1971) developed this line of thought on critical thinking as "the process of evaluating statements, arguments, and experiences". D'Angelo believes that such judgements are grounded by objective rules and evidence and consists of all the attitudes and skills used in the evaluating process. A significant feature of D'Angelo's work is his ignoring of the role of knowledge of facts and information in the execution of any critical thinking operation which is clearly inconsistent with several other authors (e.g. Ennis 1962; Glaser 1941). It is the concentration by D'Angelo on skills and attitudes, which make his ideas significant in the evolution of the concept of critical thinking.

By contrast, McPeck (1981) argues that all thinking develops and occurs within the epistemological and logical framework of discrete subject areas, and sees critical thinking as "the appropriate use of reflective scepticism" (McPeck, 1981; p.7) to establish "good reasons for various beliefs" (p. 22). For him "thinking is always

thinking ABOUT X (X being the particular topic at hand)" which specifically refers to the epistemological norms of a particular subject area and thus regards the mastery of subject-specific knowledge and skills as the arbiter of the development of critical thinking skills. The collorary of McPeck's premise of domain specific thinking is the postulation of the epistemological subject-specificity of thinking skills. "Skills are born of knowledge of, and experience in, subject areas", and hence "parasitic upon detailed knowledge of, and experience in the parent field and problem areas" (McPeck, 1981; p. 10).

Although McPeck's main concern is to warn against the danger of conceiving thinking as something that can be reduced to a body of universal skills (transcending the contexts and content areas in which thinking occurs) he admits to the importance of multi-logical thinking. The possession of a high degree of differentiated subject knowledge *per se*, cannot guarantee the achievement of reflective scepticism, and such an activity requires the intelligent integrating of knowledge. Mc Peck's ideas are supported by several theorists who promote the development of critical thinking in subjects and content areas (e.g. Brell, 1990; Rogers, 1990). These theorists believe that thinking cannot happen or be taught independently of the epistemological norms of some type of knowledge or subject domain. Meyers (1986) also sees critical thinking as active consideration stemming from the underlying epistemology of a given discipline.

Originally, Ennis (1962) proposed that critical thinking was comprised of twelve basics problem solving abilities, but he has refined his theory to include a broad set of tendencies (later called "dispositions") to his definition of critical thought. "Proficiency", he argues, "is not enough, there must be a strong tendency to exercise the tendency" (Ennis, 1980; p. 17). In other words, he believes that critical thinkers must not only possess certain skills (abilities) necessary to undertaking critical thinking tasks, but they must also have the willingness (the disposition) to use these skills. Ennis sees three concepts vital to critical thinking; "reason, reflection and focus". The combination of these three concepts configures a working definition

of critical thinking as "reasonable reflective thinking that is focused on deciding what to believe or do". In a more restricted sense, critical thinking is the directive, goal activity of an individual. Mayer (1983) and recently Halpern (1998) have supported such conceptualisation of critical thinking.

As shown in the first phrase of Ennis's definition, critical thinking entails reasonable thinking, which means:

> "...that it is good thinking that relies appropriately upon the use of good reasons. People who form beliefs or who act without good reasons are acting arbitrarily and unreasonably. Good thinking, is not arbitrary, however, because good thinking does not lead to just any conclusions. The best conclusions are those supported by the best reasons, so critical thinking must rely upon good reasons in reaching conclusions".
>
> (Norris and Ennis, 1989; p.3)

Thus critical thinking is a purposeful mental activity that relies heavily upon the use of reasoning. Since critical thinking is purposeful, reasonable thinking, a critical thinker must set his/her goals deliberately and revise the goals where necessary. At the same time an element of ambiguity seems to creep in, for whilst not arbitrary critical thinkers must be open to multiple possibilities and consider a number of alternative routes to their objectives.

Secondly, Ennis claims that critical thinking includes reflective thinking, involving the examination of both the reasonableness of their own and others' thought. Saying that critical thinking is reflective thinking is meant, "to indicate this overt, conscious aspect of good thinking" (Norris and Ennis, 1989; p. 4). The element of reflectivity allows retrospective examination of previously reasoned thoughts and subsequent actions. McPeck (1981) argues that an element of reflectivity is essential to inject possible alternatives into the act of critical thinking.

Thirdly, critical thinking is focused thinking involving deciding what to believe or do. Critical thinkers must focus their minds on the purposes or goals of the thinking process. What are they thinking about? Only when a goal has been set or a problem recognised can appropriate reasoned and reflective thought follow. A

pictorial illustration of the relationship of these three main operations is shown in FIGURE 3.1.

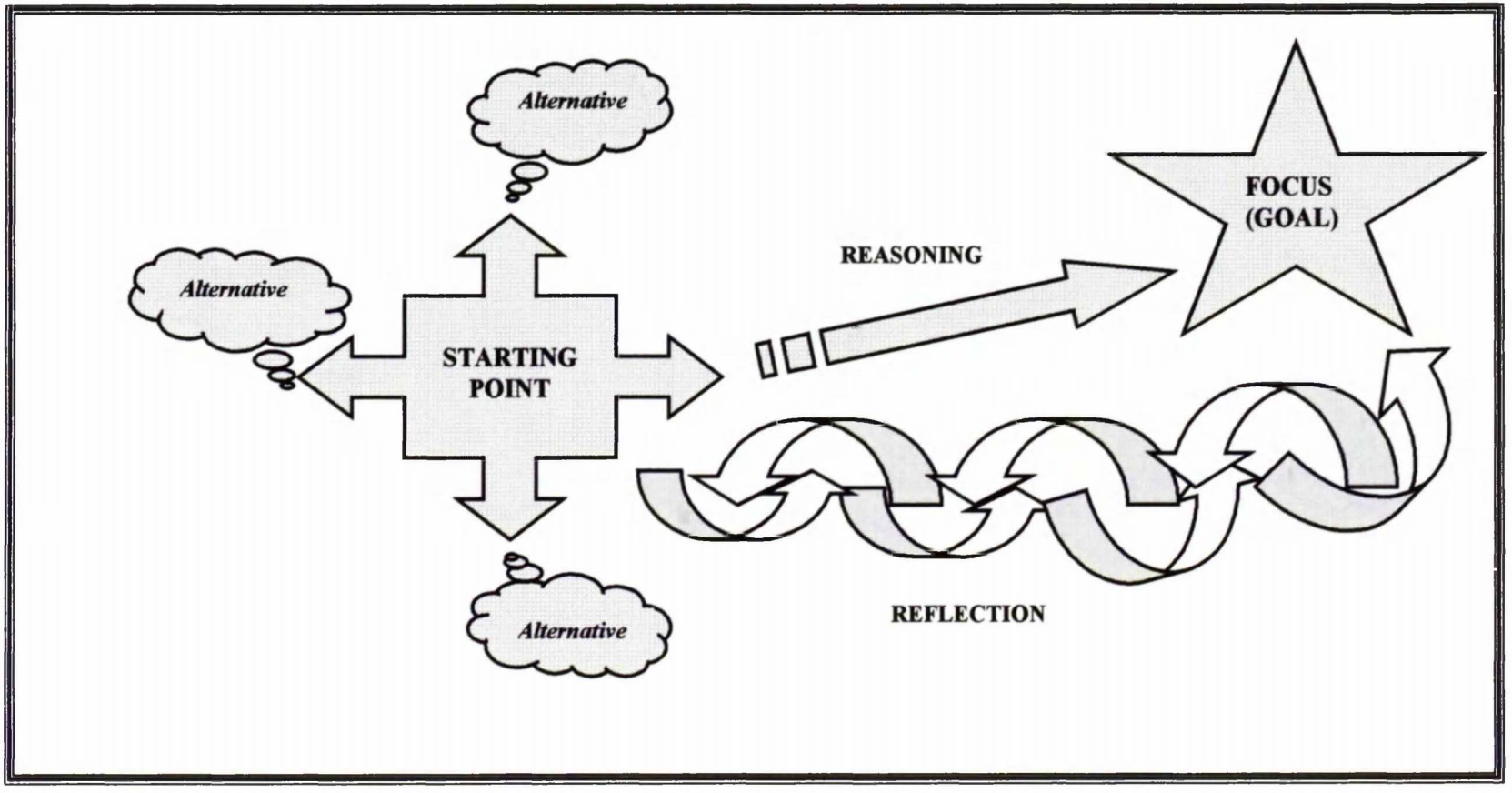
Paul (1982) introduces a further element in his definition of critical thinking. From Descartes's famous remark "I think therefore I am", Paul contends that fair-minded critical thinking activities are always interrupted by an individual's own ego and ethnocentricity coupled with the tendency for self-deception. Paul claims that an individual must be "egocentric neutral"; viz. become aware of their own biases and take step to overcome them. If they do not, individuals are likely to utilise their newly developed skills to fend off challenges to their deeply held beliefs. This, in turn, would lead to individuals "rationalising and intellectualising the biases they already have" (Paul, 1982; p. 3). Again, it is through self-reflection that egocentric and ethnocentric tendencies can be reduced to a minimum.

It could be synthesised that Paul's conception of a critical thinker is one who reasons fairly, rationally and logically with humility until a reasoned judgement can be made on issues. At the same time the critical thinker admits innate egocentric and ethnocentric tendencies. Thus, for Paul, critical thinking is best understood as a global way of disciplining and taking control of one's own thinking so as to accomplish more effectively the purpose of thinking through disciplined self-command.

Both Sternberg (1986) and Lipman (1988) concur that differing situations and differing personalities require different critical thinking skills. For Sternberg context is key and subsequently, there is no "cookbook recipe" that best suits all individuals or situations. In other words, critical thinking is a personal and *sui generis* skill. What is more, in Sternberg's argument is that critical thinking can only be measured in relation to real world events because these events are the only ones with "real" costs and "real" benefits, and so any standardisation of critical thinking evaluation becomes impossible. Sternberg's major contribution towards the development of critical thinking skills is his sub-dividing it into three basic problem solving

FIGURE 3.1

RELATIONSHIP OF THE THREE MAIN OPERATIONS OF CRITICAL THINKING



categories: viz. meta-components, performance components and knowledge-acquisition components.

Metacomponents refer to higher order thinking processes that are used to plan what we are going to do, monitor performance while it is being done, and evaluate performance after the task is done. Strategically, this includes:

> "...recognising that a problem exists, defining the nature of the problem, deciding on a set of steps for solving the problem, ordering these steps into a coherent strategy, deciding upon a form of mental representation for information, allocating one's time and resources in solving a problem, monitoring one's solution to a problem as the problem is being solved, and utilising feedback regarding problem solving after one's problem solving has been completed"
>
> (Sternberg, 1986; p. 9)

In a sense, Sternberg's meta-components resemble Dewey's five step reflective problem solving processes that started with problem recognition and ended with solution evaluation. Performance components are lower order processes used to execute the instructions of the metacomponents and to provide feedback to them. It varies by domain of performance, and some examples might include inductive and deductive reasoning, spatial visualisation, and reading (Sternberg, 1985). Knowledge acquisition components are "the processes used to learn concepts or procedures" and these include selective encoding (screening relevant information), selective combining (relating relevant information), and selective comparison (relating old information to new information).

It could be argued that, Sternberg's three components of critical thinking closely resemble many of Ennis's "abilities". In a sense, Sternberg borrowed Ennis's concept, renamed them, and placed them into categories of cognitive difficulty. Sternberg's main contribution to critical thinking rests in his ability to successfully integrate many of the important components of other theories into a single, three-stage "real life" applicable problem-solving model. Not only does he identify several key components of critical thinking, but he also states why context and external factors are important in relation to those abilities.

From the discussion so far, it appears that Dewey's thinking marks the watershed conceptual definition of critical thinking. Ennis's goes on to describe what critical thinking is. Paul proposes how critical thinking should be used and Sternberg (1986) points out the limitation of critical thought in "real" world settings. It could be argued that McPeck's, Sternberg's, Ennis's, and Paul's ideas have strong ascendancy over Brookfield's (1987) conception of critical thinking.

Like McPeck, Brookfield defines critical thinking as a productive, positive, rational and emotive process that occurs in a contextually specific domain (Brookfield, 1987). Additionally, Brookfield, like Sternberg, claims that the process of critical thinking is "person specific". Such an assertion is partially because he sees emotions as being central tenets to the critical thinking process (and emotion is personal in nature), and partially because no two contexts in which critical thinking occurs are alike. Like Ennis and Paul, Brookfield sees the connection between personal interaction and critical thinking as essential for cognitive growth because:

> "...when people undertake critical thinking in groups, their private interpretation gain legitimacy as others venture similar interpretations and realisations. Realising that others are experiencing the discrepancies, ambiguities, and contradictions we feel grants a degree of legitimacy to our own perceptions. As a consequence, we are more likely to follow through our own process of critical thinking"
>
> (Brookfield, 1987; p. 232)

However, Brookfield's view is more general, insofar as he sees all daily interaction as critical thinking processes. For Brookfield "we are critically thinking whenever we question why we, or our partners, behave in certain ways within a relationship" (Brookfield, 1987; p. 4). Brookfield's main contribution to critical thinking is to suggest that all life activities involve critical thinking skills to a greater or lesser degree.

Brookfield, despite contending that each individual may experience critical thinking in a unique fashion, believes people typically pass through a number of identifiable and commonly experienced phases of critical thought; i.e. trigger events, appraisals, explorations, alternative perspective development, and integration.

Additionally he identifies two important themes: what critical thinkers should remember when they think, and skills necessary to conduct critical thinking tasks. "Reflective scepticism" for Brookfield requires that critical thinkers "do not take things as read", and that they are "wary of claims to universal truth or to ultimate explanations" (Brookfield, 1987; p. 5). Instead of conceptualising in black and white, Brookfield sees critical thinkers as viewing all the shades of grey.

Beyer (1988) distinguishes critical thinking from "micro thinking skills" such as those illustrated in "Bloom's Taxonomy" and those typically taught in logic and philosophy (inductive, deductive, and analogical reasoning). Beyer also differentiates critical thinking from higher level "thinking strategies" such as problem solving and decision making which he argues are more complex cognitive tasks aimed at the process of developing support to formulate a particular solution to a problem. Such higher order "thinking strategies" consist of a hierarchical sequence of subordinate procedures for example, (a) recognising a problem; (b) representing a problem; (c) devising a solution plan; (d) executing the plan; and (e) evaluating the solution.

Beyer conceptualises critical thinking as a repertoire of specific operations, situated between micro thinking skills and major thinking strategies in terms of their complexity and function. These critical thinking skills may be used independently or in any combination and order (in contrast to micro thinking skills and thinking strategies where each level subsumes those antecedents to it). In Beyer's list, critical thinking skills include the ability to "distinguish between verifiable facts and value claims, distinguish relevant from irrelevant information, determine the factual accuracy of a statement, determine the credibility of a source, identify ambiguous claims or arguments, identify unstated assumptions, detect bias, identify logical fallacies, recognise logical inconsistencies in a line of reasoning, and determine the strength of an argument or claim" (Beyer, 1988; p. 57). Therefore, there is seen to exist a hierarchical order of micro thinking skills, critical thinking operations and thinking strategies (the latter including problem solving and decision making). Such contentions imply that critical thinking will necessarily include micro thinking skills

and as argued by Ziedler *et al.* (1992), is a necessary condition for a successful execution of problem solving strategies.

One silver thread running through these major theories of critical thinking appears to be that the combination of reasoning, self-reflection or self-regulation (Facione *et al.*, 1995) and personal beliefs are a main thrust of any critical thinking operation. However, analysis of critical thinking definitions from the philosophical point of view starting with the work of Socrates 2 500 years ago (Paul, 1997) to the present day, shows a heavy reliance on reasoning and logic as an important aspect of critical thinking (Black, 1952; Hudgins, 1977; Siegel, 1989). Black (1952) sees logic as "the art of improving reasoning" and driving "the practical interest of self-betterment and theoretical interest of understanding" (Black, 1952; p. 9). Reasoning, on the other hand, refers to a "complex pattern of thinking and acting" (p.27) which includes the acts of "observation, memory, and the testing of plausible solutions of a problem" (p. 27). Thus, inquiry method as promoted by philosophers is dependent upon the effective gathering of data, or reliable facts from experience by employing a step-by-step logical process of critical thinking (Hudgins, 1977). There is no place for internal dialogue or reflection in such logical process of problem solving activity.

Siegel's (1992) contribution to the debate from the philosophical point of view argues that the coalescence of critical thinking and rationality is the main thrust of critical thinking. By definition, critical thinking is an act of focusing on reason and the power of reason to warrant or justify beliefs, claims and actions. Critical thinking according to Siegel has two components: reason assessment and critical spirit. With respect to the first component, Siegel argues that to seek reasons, one has to recognise and commit oneself to principles, for principles are needed to determine the relevance and strength of reasons. To put it another way, for Siegel, critical thinking is "principled thinking". Principles according to Siegel are logic which "govern the seeking of reason by proper inference".

Nevertheless, merely to assess reason is not enough; a critical thinker, according to Siegel, must also have attitudes, dispositions, habits, and character traits to possess critical attitudes or spirit:

> "I take the critical spirit to be a complex of dispositions, attitudes, habits of mind, and character traits. It includes *dispositions*, for example the dispositions to seek reasons and evidence in making judgements and to evaluate such reasons carefully in accordance with relevant principles of reason assessment *attitudes*, including a respect for the importance of reasoned judgement and for truth, and a rejection of partiality, arbitrariness, special pleading, wishful thinking, and other obstacles to the proper exercise of reasoned assessment and reasoned judgement, *habits of mind* consonant with these dispositions and attitudes such as habits of reason seeking and evaluating of engaging in due consideration of principles of reason assessment, of engaging in fair-minded and non self-interested consideration of such reasons and *character traits* consonant with all this"
>
> (Siegel, 1992; p. 105 –106)

Siegel however, writes nothing about how to nurture the kind of character that values higher order thinking. What is significant to him is the ability to focus on logical reasoning – reasoning which is germane in justifying beliefs, claims and actions.

The role of attitude in critical thinking operation is also significant in Hudgins's (1977) definition of critical thinking. Hudgins argues that critical thinking is "a general attitude of searching for evidence relevant to conclusions and that attitude must be supported by an array of intellectual skills germane to the analysing and evaluation of arguments" (p. 179). Hudgins notes four attributes common to the concepts of critical thinking: comprehension; use of evidence; evaluation and evidence and lines of reasoning; and an awareness of assumptions. Such an assumption purports being aware of the logical thinking process, as well as the beliefs underlying one's assumptions.

Kitchener (1983) concludes that the definition of critical thinking preferred by philosophers is synonymous with traditional logic or the *hypothetico-deductive* method of scientific reasoning. Dewey refutes the role of syllogistic reasoning by claiming that people do not arrive at conclusion by the use of reasoning, although they might use formal logic to convince others of the validity of the conclusion. Instead, Dewey argues reflective thinking guided by reason and the detection and

testing of relations. Thus, psychologists, pioneered by Dewey, tend to see critical thinking as a process of inquiry or more general problem solving activity guided by self-reflection and personal beliefs.

3.2.1. Summary of Theories

Discussion of the conceptions and definitions of critical thinking in the preceding section reveals that all the aforementioned theorists contribute to the field of critical thinking in some significant way. In essence, Dewey identifies how reflective/critical thinking should be practised; Paul states why intrapersonal and interpersonal dialogue are necessary for critical thinking; Sternberg discusses the limitation of critical thinking under real world constraints; and Brookfield shows how critical thinking skills can be used in everyday life and explains what typical phases of critical thinking should be.

Ennis, however, appears to have devised a theory that is the only one which specifically provides a measurable set of criteria for critical thinking. It has been revised over the last 20 years partially as a result of the insight from these other theorists and partially on his own accord. It could be argued that the main reason why Ennis's theory is so viable today is because of this continued re-evaluation and modification. Of all the critical thinking theories discussed in this overview, it is the researcher's opinion that Ennis's theory is the most inclusive, gives the greatest detail, is the easiest one to assess, and the one most appropriate for use within the context of this study. For these reasons Ennis's definition of critical thinking is the predominant one used for the rest of this thesis.

3.2.2. Further Elaboration of Ennis's Conception of Critical Thinking

Critical thinking is a mental process that is focused on deciding what to believe or do. In making decisions, humans rely on information, background knowledge, and previously accepted conclusions. These elements form the basic

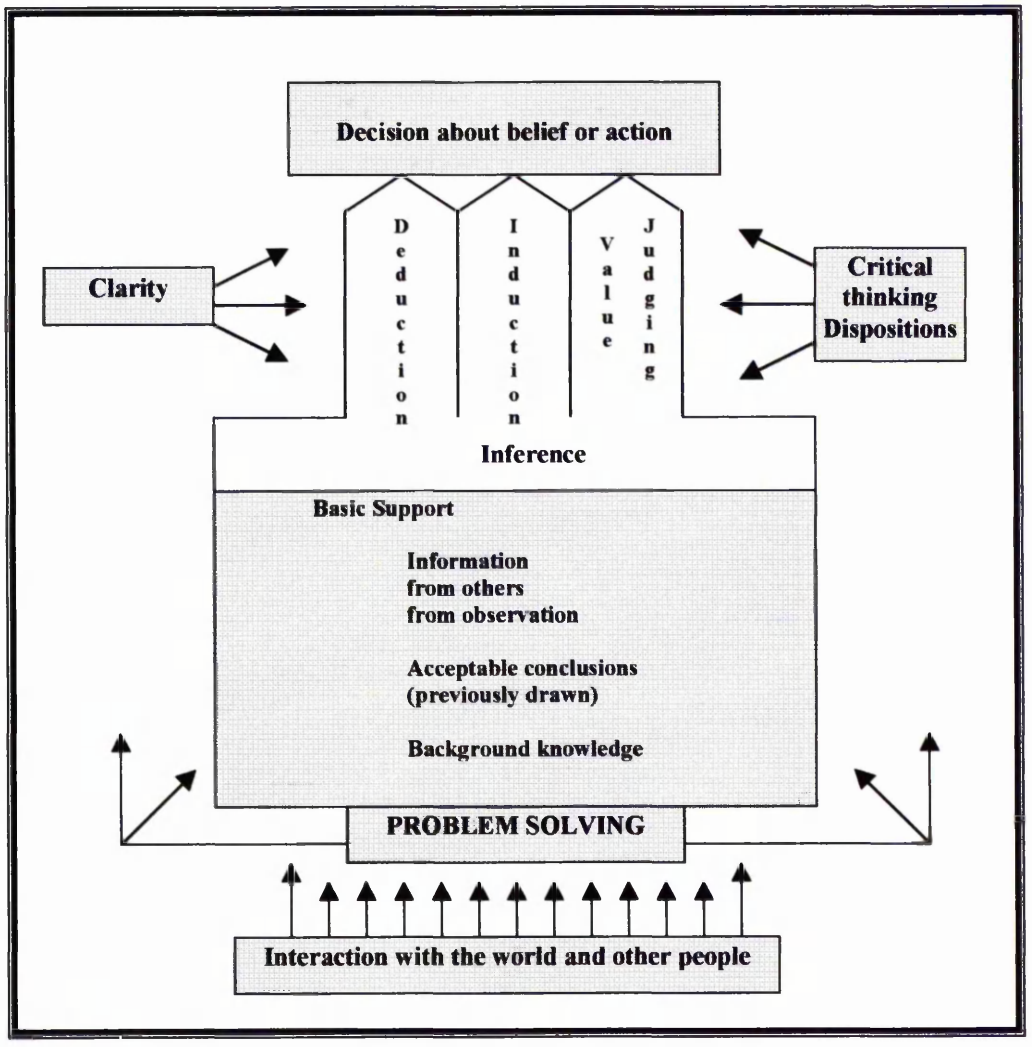
support for a decision. The link between the basis for the decision and the decision itself is a process called inference. Thus, decisions are inferred on the basis of known information and previously accepted conclusions. FIGURE 3.2 depicts the logical relationships in the critical thinking process. Although FIGURE 3.2 implies the direction of the process is from bottom to top, this does not mean that critical thinking in any practical sense necessarily follows an ordered, linear path. Indeed, critical thinking can proceed in many directions and can stop, restart, and retrace.

The problem solving box near the bottom of FIGURE 3.2 indicates that the process of critical thinking is viewed broadly as an element of problem solving. The process of critical thinking ends in a decision about belief or action indicated by the decision box at the top of the figure. The interaction box at the bottom of the FIGURE 3.2 indicates that the whole process of reaching a decision usually rests in a context of interaction with the world and other people. The basic support box acts as the starting point of critical thinking, which consists of information from others and observation, previously accepted conclusions and background knowledge. The inference columns indicate three basic type of inference processing which result in the final decisions.

The points in the column indicate the direction of the logical inference. The disposition box and the arrows depict the need to diffuse critical thinking dispositions throughout the whole critical thinking process. Finally, the clarity box and the arrows emanating from it illustrate how a concern with clarity must permeate the process of critical thinking.

FIGURE 3.2

A DIAGRAMMATICAL ILLUSTRATION OF ENNIS'S CRITICAL THINKING DEFINITION



3.2.3. The Parallelism of Ennis's Definition of Critical Thinking and the Context of the Integrated Secondary School Science Curriculum (ISSSC)

The term "problem solving", is frequently used synonymously with "scientific method", "scientific thinking", "critical thinking" and "inquiry skills". Although some distinctions are made amongst them, it is clear that all of them have reference to some portion of the ability to solve problems (Champagne and Klopfer 1977), and as Larkin (1979) asserts:

> "All the sciences, both pure and applied, are centrally concerned with developing and systematising knowledge useful for solving various kind of problem. Hence, education in the sciences must address the crucially important task of teaching children to become proficient problem solvers"
>
> (Larkin, 1979; p. 191)

The relationship between critical thinking and problem solving is consistent with Ennis's generalisation (see also FIGURE 3.2), and such a conception of critical thinking would appear to be in harmony with the ultimate aims of the ISSSC; i.e.

> ".. to provide children with knowledge and skills in science, to develop their **scientific thinking** as well as to inculcate good moral values in them. This will enable children to understand and appreciate science and its application to everyday life as well as in national development. It seeks also to produce responsible citizens who are able to participate in **problem solving** activities and **make decisions** for the well being of Man"
>
> (Ministry of Education, 1989)

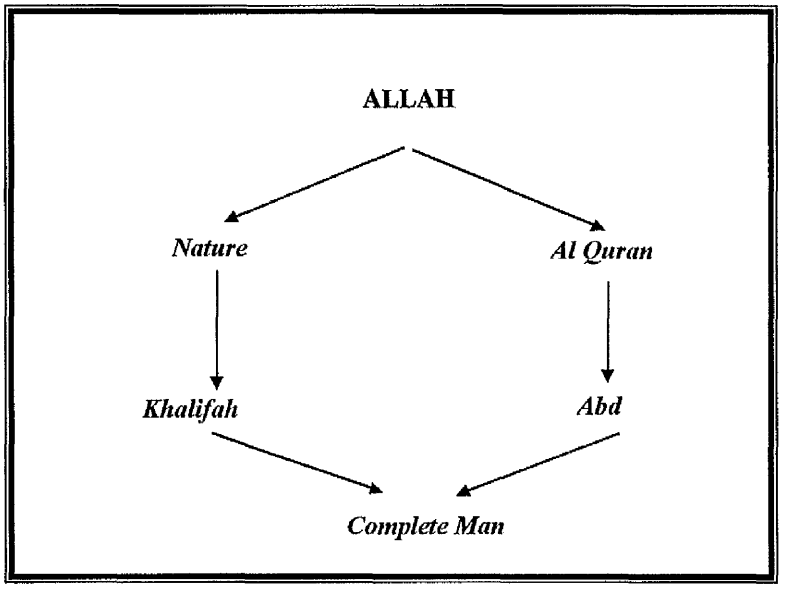
For Ennis, the process of solving problems will end in a decision about a belief or an action, a philosophy which coincides with the ultimate aim of ISSSC quoted above, that is the making of decisions for the well being of Man. Such an aim, is also a central feature of the working paradigm of the Malaysian science education (Salleh, 1995) that posits that Nature and Al Quran are ALlah's great endowment to Man (FIGURE 3.3). Through the teaching of Al Quran, Man can realise himself as the true *abd* (servant) of Allah, and through his interaction with nature[5], Man can perform his role as a *khalifah*[6] (vicegerent) of ALlah. In other words, Man is encouraged to bring about innovation within the framework of Nature, yet owe his allegiance to ALlah the Almighty. Thus, only by actualising his role as an *abd* and

[5] Nature is a meant to be "read" and studied by Man. In it is a sign for those who think, reflect, know and understand them.

khalifah of ALlah, can Man establish himself as an *insan kamil* (complete man). The complete man has the ability to discriminate and hence make judgements, which result in the actions that he takes regarding the issues and problems that are before him.

FIGURE 3.3

THE WORKING PARADIGM OF SCIENCE EDUCATION IN MALAYSIA



Ennis's conceptualisation of critical thinking perceives the process of reaching a decision as resting in a context of interaction between an individual, and other people. Such a view is also consistent with the Islamic philosophical thoughts underpinning the ISSSC. Man, in performing his role as an *abd* and *khalifah* in this world, has to consider not only his obligation towards ALlah *(relationship between the creator and the creatures),* but also his relationship among ALlah's creation *(relationship among the creatures created).*

[6] Khalifah: someone who inherits the earth and has supremacy in it (Al Quran 2:30; Al Quran 6:165).

The Al Quran takes it as axiomatic that knowledge is a prerequisite for wisdom and power. The possession of in-depth knowledge, coupled with adroitness in relevant critical thinking skills, equips Man with the power to act intelligently and effectively. The nature of learning science requires certain background knowledge since science, *inter alia*, is a hierarchical building of concepts. The ability to recognise and then solve scientific problems subsumes the process of science learning such as observation etc. (see also FIGURE 3.2). The generation of answers that will confirm or refute belief (scientific theory) or inform a decision to be taken is the ultimate aim of ISSSC, and to help children perform at this level learners must know how to self-acquire knowledge, perform activities of science either theoretically or experimentally, administer, manage and make decision about scientific activities, but more than that, grow and develop at the spiritual and affective levels. In the Islamic context, scientific method is not solely the application of the processes mentioned above, but places equal importance on other ways of knowing such as intuition and revelation.

3.3. DIMENSION OF CRITICAL THINKING

From Ennis's work thinking in general and critical thinking in particular consists of at least three major dimensions: knowledge, operations or abilities and attitude or dispositions. This conception of critical thinking as a three-faceted enterprise is consistent with Glaser (1941), McPeck (1981), Paul (1982), Sternberg (1986), Beyer (1988) and Siegel (1992), and is supported by Newmann (1990) and several others involved in the study of thinking (e.g. Bransford *et al.*, 1986; Costa and Lowery, 1989; Facione *et al.*, 1995; Ronning *et al.*, 1984; Swartz and Perkins, 1989).

3.3.1. Knowledge

Studies comparing experts and less experienced individuals in areas such as engineering, computer programming, physics, mathematics and even reading comprehension (Hunt, 1978; Glaser, 1984) have shown that effective thinking and problem solving depends strongly on the nature and organisation of the knowledge available to individuals. For instance, studies conducted by Larkin *et al.* (1980) revealed that effective problem solvers require information and specialised problem solving training within specific domain of knowledge. Similarly, Greeno (1980) and Simon (1980) conclude that there is no such thing as expertness without knowledge. Such evidence suggests that effective thinking and problem solving demands the possession of an in-depth knowledge structure of the thinkers and problem solvers.

Beyer (1987) distinguishes three types of knowledge: general heuristics, knowing something about the nature of knowledge, and domain specific knowledge. General heuristics are principles based on experience that usually lead to the desired result; it is a kind of knowledge that will result in the accumulation of experience and hence guides and shapes how one goes about thinking and solving problems. Knowing about the nature of knowledge includes realising what we believe in as knowledge is highly selective, fragmentary, interpretative, ever changing and tentative. Awareness of this aspect of knowledge appears to influence how someone goes about thinking as well as how to treat other people's thinking. And the third dimension of knowledge component is domain specific knowledge. This dimension of knowledge includes knowing various reliable data in a particular field of knowledge, including specific analytical concepts useful for generating, organising and making sense of information in specific fields (Mayer, 1983; McPeck, 1981; Nickerson, 1990). It could be argued that if domain specific knowledge is properly taught, it will inevitably entail higher order thinking because adequate mastery of most subjects requires the use and manipulation of knowledge in subject areas (Bransford *et al.*, 1986; Glaser, 1984; McPeck, 1981; Ronning *et al.*, 1984; Newmann, 1990).

However, knowledge *per se* is only of value when it can be put to some use. That is, applied to critical thinking and the solving of problems. Correspondingly, an important hallmark of intelligence is often referred to as the possession of operational skills that will allow students to exploit the knowledge that they have acquired (Brown and Champione, 1981). This concern on the application of previously acquired knowledge leads to the following discussion on the concept of cognitive and metacognitive abilities.

3.3.2. Operations or Abilities

Thinking in general consists of some type of mental activity, which can be classified in terms of the operation that the mind seems to perform when engaged in the process of thinking. Beyer (1987) and many others (Bransford, 1979; 1984; Costa and Lowery, 1989; Chipman *et al.*, 1985; Swartz and Perkins, 1989) contend that thinking operations are of two general types: cognition and metacognition.

Cognition consists of those operations which are used to generate and find meaning. These operations encompass a wide spectrum of complex strategies, such as problem solving, decision making or conceptualisation as well as more discrete and less complex skills such as analysing and synthesising. Metacognition, on the other hand, consists of those operations by which we direct and control these meaning-making strategies and skills. It refers to one's knowledge about, awareness of, and control over one's own mind and thinking (Beyer, 1987; 1988; Costa, 1985; Swartz and Perkins, 1989). Although the processes involved often vary (Blagg *et.al.*, 1988), basically metacognition consists of those operations of planning, monitoring and assessing one's thinking (Flavell, 1979).

Therefore, any act of critical thinking, or thinking in general will involve the combination of operations which produce meaning (cognitive) and those that direct how the meaning is produced (metacognitive) operations. It is the researcher's opinion that the act of informing students about the uses of metacognitive strategies

as well as their cognitive ones will eventually help students to become aware of the thinking operations that are being operationalised. Eventually, the knowledge in the students' memory repertoire will be exploited accordingly and more than this, they will be able to apply and transfer those operations beyond the classroom. Thus, it is argued, by placing equal emphasis on cognitive and metacognitive strategies in addition to the systematic development of a well-organised knowledge base, the speed with which people can become able to think effectively in a variety of knowledge-rich domains will be increased. A summary of cognitive and metacognitive operations as conceptualised by Ennis is given in TABLE 3.1.

3.3.3. Attitudes or Dispositions

It is almost a truism that in a perfect world, subjects' resources or domain specific knowledge (§3.3.1; page 97) should be adequate to characterise their critical thinking and problem solving performance. Mildenhall (1988), in his literature analysis of several problem solving studies discovered that:

> "...the world is far from perfect, and the problem solver's performance is affected by their belief systems: belief in how they think the world works, belief in their own abilities"
>
> (Mildenhall, 1998; p. 56).

Thus, other affective dimensions such as interest, motivation, confidence, perseverance and willingness to take risks has been considered in the problem solving research. In a similar vein, critical thinking theorists argue that thinking requires something more fundamental than knowledge or skills, namely a set of attitudes or dispositions (Beyer, 1987; 1988; Costa and Lowery, 1989; Ennis, 1985; Newmann, 1990; Norris and Ennis, 1989). These dispositions are classified by Beyer (1987; 1988) as those that relate to thinking in general and as those that relate to specific cognitive operation. With respect to the former, the attitudes involved are to suspend judgement, a tendency to be reflective (that is to take time to think problems through for oneself, rather than acting impulsively or automatically accepting the views of others, a respect for evidence and for the use of reason). On the other hand, attitudes that relate to the latter are willingness to consider from other points of view rather than one's own, a desire to secure as much as information as possible before

making a judgement, and a willingness to identify additional alternatives after an apparently acceptable alternative has been produced.

TABLE 3.1

THE CLASSIFICATION OF ENNIS'S CRITICAL THINKING OPERATIONS (COGNITIVE AND METACOGNITIVE OPERATIONS)

COGNITIVE OPERATIONS
Elementary Clarification
1. Focusing on a question
2. Analysing arguments
3. Asking and answering questions that clarify and challenge
Basic Support
4. Judging the credibility of the source
5. Making and judging observations
Inference
6. Making and judging deduction
7. Making and judging induction
8. Making and judging value judgement
Advanced Clarification
9. Defining terms and judging definitions
10. Identifying assumptions
METACOGNITIVE OPERATION
Strategies and Tactics
11. Deciding on an action
12. Interacting with others

Facione *et al.* (1995a) proposes that critical thinking dispositions can be classified into seven major dispositions: **T**ruth Seeking, **O**pen Mindedness, **A**nalyticity, **S**ystematicity, Self **C**onfidence, **I**nquisitiveness and **M**aturity. These critical thinking dispositions are discipline neutral and encompass a generalisable description of the ideal critical thinker across multiple contexts and situations (The Delphi Report, 1990). TABLE 3.2. summarises Ennis's list of critical thinking dispositions according to those seven factors that dispose a person towards employing critical thinking operation (cognitive and metacognitive).

FIGURE 3.4 illustrates diagrammatically the inter-relationship between knowledge, operations and dispositions. From FIGURE 3.4, it can be summarised that the possession of in-depth knowledge structure and the adroitness in cognitive as well as metacognitive operations will not necessarily guarantee the successful completion of critical thinking or problem solving operations. Besides, students need to establish certain kind of dispositions within themselves, which intrinsically motivate and inspire them to think critically effectively. As a result, whenever students are bombarded with issues to be tackled or problems to be solved, these three dimensions of critical thinking will become their cognitive and affective asset, which ultimately inspire and guide them towards the achievement of the desired thinking and problem solving outcomes.

TABLE 3.2: CRITICAL THINKING DISPOSITIONS

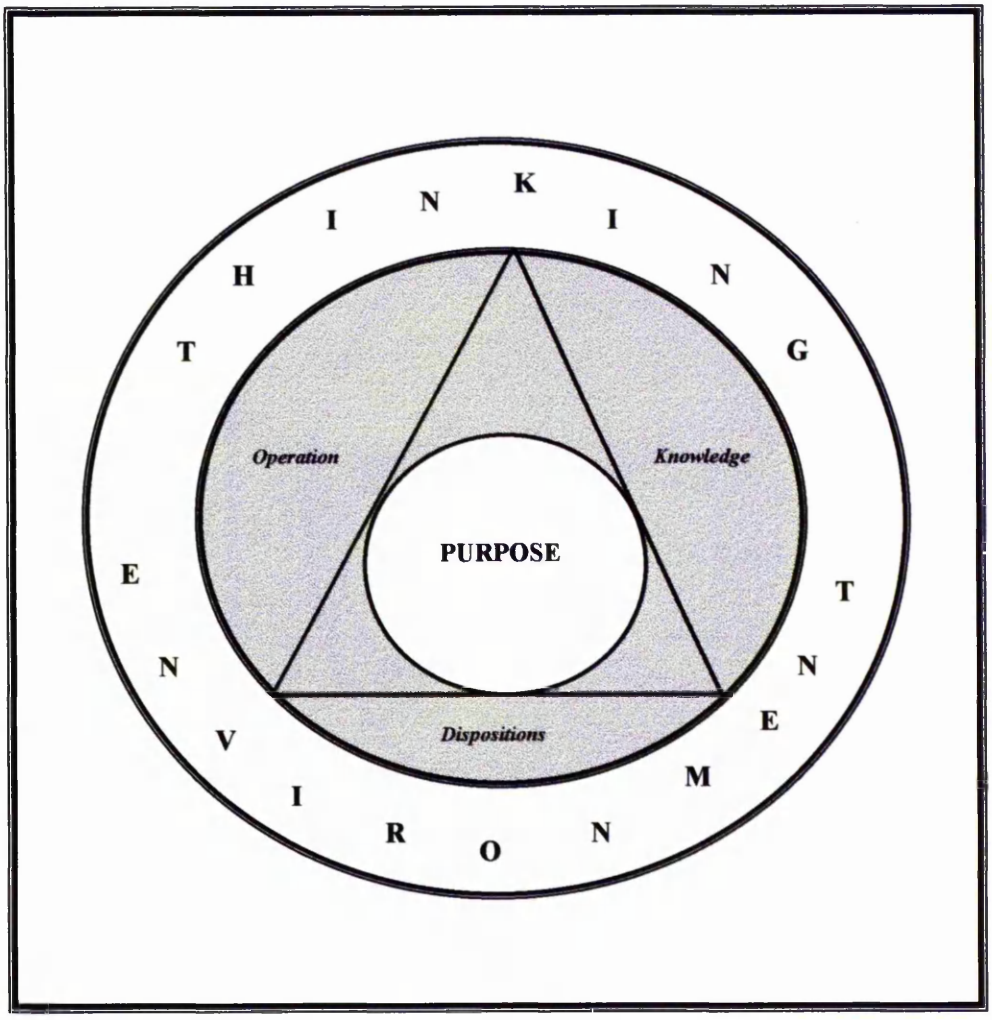
FACTOR	DEFINITION*	DESCRIPTION**
Truth Seeking	The disposition of being eager to seek the truth, courageous about asking questions, and honest and objective about pursuing inquiry even if the findings do not support one's interests or one's preconceived opinions	Seek a statement of the thesis or question
Open Mindedness	The dispositions of being open-minded and tolerant of divergent views with sensitivity to the possibility of one's own bias	Seriously consider points of view other than their own; Reason from starting point which they disagree without letting the disagreement interfere with their reasoning; and Withhold judgement when the evidence and reasons are insufficient
Analyticity	The disposition of being alert to potentially problematic situations, anticipating possible results or consequences, and prising the application of reason and the use of evidence even if the problem at hand turns out to be challenging or difficult	Seek reasons; Take a position and change a position when the evidence and reasons are sufficient to do so; Take into account the total situations; Seek as much precision as the subject permits
Systematicity	The disposition towards organised, orderly, focused, and diligent inquiry	Deal in an orderly manner with the parts of a complex whole; Keep their thinking relevant to the main point
Self Confidence	The level of trust one places in one's own reasoning processes	Employ their critical thinking abilities Keep their thinking relevant to the main point
Inquisitiveness	Values of being well-informed, wants to know how things work, and values learning even if the immediate payoff is not directly evident	Try to be well-informed
Maturity	Targets how disposed a person is to make a reflective judgement	Look for alternatives; Are sensitive to the feelings, level of knowledge, and degree of sophistication of others

* Definition based upon the definition given in the California Critical Thinking Disposition Inventory

** The description of critical thinking dispositions based upon Ennis's list of critical thinking dispositions

FIGURE 3.4

DIMENSION OF CRITICAL THINKING



3.4. PEDAGOGICAL CONTENT KNOWLEDGE ABOUT CRITICAL THINKING: APPROACHES TO TEACHING CRITICAL THINKING SKILLS

There is considerable literature in the field of how to teach thinking and problem solving. A review reveals that in an endeavour to categorise approaches to teaching thinking, Brandt (1984) proposed, Costa (1984; 1985) defined and Swartz and Perkins (1989), Costa and Lowery (1989) refined and Sholseth and Watanabe (1991) recognised three main categories or level of teaching thinking. These three categories are teaching *for* thinking, teaching *of* thinking and teaching *about* thinking. Essentially, teaching *for* thinking is about integrating thinking skills into conventional subject matter which in turn, is used as a vehicle for thinking. Teaching *of* thinking on the other hand refers to direct teaching of thinking skills independently of any academic subjects. Although content may be involved, it is not the major focus of the instruction. On the other hand, teaching *about* thinking involves metacognition, studying brain functioning and examining the ways in which knowledge is produced. Metacognition helps students to plan as well as evaluate their thinking. Examples of strategies involved in monitoring students' thinking may include: self talk; asking students questions and making suggestions about their work (thinking aloud); students may be asked to describe reasons for a solution (paired problem solving); students take turn as active problem solvers and listeners, and thought tracing; or they may use a journal to record their train of thought (Gilbert, 1994; McTighe and Schollenberger, 1991; Wilson and Wing Jan, 1993). Additionally, studying brain functioning and the epistemological basis of how knowledge is produced by famous people in their fields will shed light on the types of effective thinking (Costa, 1985).

Ennis (1989) describes four distinct categories, which roughly correspond to the categories *for*, *of* and *about* thinking in the following terms: "general", "infusion", "immersion" and "mixed". In terms of approaches, "infusion" is similar to the previous category of teaching *for* thinking. "Immersion" seems to parallel

more closely to the teaching *of* thinking and "general" approach is a close resemblance of teaching *about* thinking.

3.4.1. Direct or Stand Alone Approach

This approach consists of teaching thinking skills separately from subject matter content (Costa and Lowery, 1989; Sternberg, 1984; Nickerson, Perkins and Smith, 1985) and instructing students how to internalise and transfer the skills to various subjects and situations. Synthesis of the findings from research in specific thinking processes and the organisation of these processes in the human mind (Beyer, 1987; 1988; De Bono, 1987; Feely, 1976; Feuerstein *et al.*, 1980; Siegel, 1989) general approach as described by Ennis (1989) is:

> "...an approach that attempts to teach critical thinking abilities and dispositions separately from the presentation of content of existing subject matter offerings, with the purpose of teaching critical thinking"
>
> (Ennis, 1989; p.4)

Proponents of this approach of teaching thinking presume that cognitive skills are muscles of mind, which can be rejuvenated through extensive practice. Although they recognise the role of knowledge, for the purpose of thinking, they argue that skills are much more important because they are tools that permit knowledge to be used or applied to the solution of new problems (Newmann, 1990). Several examples of projects that were designed according to the general approach are Philosophy for Children (Lipman, 1991), the CoRT Thinking Programme (De Bono, 1991), Odyssey (Wright, 1991), Instrumental Enrichment (Feuerstein, 1980), Higher Order Thinking Skills (HOTS) (Pogrow, 1991), Tactic for Thinking (Marzano, 1991) and Improving Minimal Proficiencies by Activating Critical Thinking (IMPACT) (Winocur, 1991).

Although this approach of teaching thinking seems to portray critical thinking as an unrelated and discrete skill, if it is properly taught, it would not merely lead to what Perkins (1986) describes as skills' acquisition and internalisation; viz. practising the application of critical thinking skills so that it become automatic, but more than that, students would also be able to transfer the skill beyond the particular

teaching and learning context. In this sense, high road transfer (Perkins and Solomon, 1987) is encouraged; a situation in which the acquired skills are applied and adapted to other contexts and situations.

3.4.2. Infusion or Embedded Approach

This approach is rooted from McPeck's (1981) conception of critical thinking as epistemological knowledge bound. This epistemological knowledge laden of critical thinking instruction maintains that the only way to teach critical thinking is through a given field, learning of subject matter and methods of that field. The infusion approach means embedding the teaching of critical thinking within the established curriculum. Based on expert-novice studies and problem solving and reasoning in specific domain of knowledge, in this approach general as well as specific thinking skills are taught and then applied directly to the particular subject matter they are studying.

Proponents of this approach include Glaser (1984), Resnick (1987), Swartz (1987) and McPeck (1981; 1990), Brell (1990) and Rogers (1990). These theorists believe that critical thinking cannot be taught independently of the epistemological norms of some type of knowledge and subject matter. As Ennis (1989) has it:

> "The infusion of critical thinking into subject matter instruction is deep, thoughtful, well understood subject matter instruction in which students are encouraged to think critically in the subject, and in which general principles of critical thinking dispositions and abilities are made explicit"
>
> (Ennis, 1989; p. 5)

Unlike the general approach proponents, the content oriented view of thinking assumes that content and intellectual processes are mutually reinforcing, and the interrelationships between knowledge structure and cognitive processes determine the kind of thinking skills to be exercised in the classroom. By understanding a particular discipline in depth, students are able to comprehend the cognitive processes that they use during learning (Cabrera, 1992).

Therefore, in this approach of teaching thinking, the key for teaching critical thinking thus becomes a cadre of expert teachers "who understand the structure of their particular discipline and how it is different from that of other discipline and who can pass on such awareness to their students" (Chambers, 1988; p.5). Arguably, this approach of teaching thinking when used repeatedly will help the students not only to internalise the skills so that they will be able to apply them with little conscious effort, but also produce low-road transfer; transfer of skills which lead to the automatically triggering of well-practised routines in similar contexts or situations (Perkins and Solomon, 1987).

3.4.3. Immersion Approach

This approach does not involve teaching thinking skills, rather it allows good thinking to develop naturally as a result of students being fully engaged or immersed in content-related activities which call for higher order thinking. Advocates of this approach of teaching thinking assume that students learn to use thinking skills as they became deeply immersed in the subject. Prawat (1991) argues that

> "An in-depth understanding of content is thought to constitute both a necessary and sufficient condition for the development of higher order thinking"
>
> (Prawat, 1991; p. 3)

In this type of thinking approach, students are provided with repeated practice in complex cognitive activities with the assumption that they will eventually develop the necessary skills to successfully engage in high level thinking. Synonymous as thought-provoking kind of subject matter instruction in which students are highly immersed in the subject while critical thinking principles are not made explicit, students may not realise that they are engaged in specific thinking strategies. Thus, improved thinking, as Yildrim (1991) suggests, is a by-product of dealing with specific content.

3.4.4. Mixed Model

Baron and Sternberg (1987) have put this kind of teaching approach forwards in which thinking skills are taught separately as a separate course as well as being infused in the curriculum. Ennis (1990) describes the mixed model as consisting of a combination of the general approach with either infusion or immersion approach. Amongst those who strongly supported this kind of approach are Sternberg (1987), Nickerson (1988) and Perkins and Solomon (1989).

Review of literature on the related issue reveals that the effectiveness of the teaching thinking approaches (§3.4.1 - §3.4.4) was measured by most researchers primarily upon its ability to: stimulate cognitive skill acquisitions, encourage transfer as well as increase students' academic achievement. In the following, the effect of the approaches on the three variables will be presented, which in turn equips us with sufficient guidelines in selecting the most appropriate critical thinking programme to be implemented within the existing curriculum.

3.5. STUDIES COMPARING THE EFFECTIVENESS OF APPROACHES OF TEACHING THINKING SKILLS

Out of eight studies reviewed 50 percent show that direct teaching of critical thinking has a significant impact in increasing students' cognitive abilities. The effect of a stand-alone approach to students' cognitive skills acquisition is shown by Herrnstein *et al.* (1986) through a yearlong study on 800 Venezuelan seventh grade students gathered from 24 different schools. By employing an experimental technique with no treatment-control group design, students were randomly sub-divided into experimental and control groups. The experimental groups met four days a week. The treatment group attended lessons including instruction on six different types of general thinking skills: foundations of reasoning, language understanding, verbal reasoning, problem solving, decision making, and inventive thinking. The control group proceeded with their normal classroom instruction. Students'

progression on general thinking skills was evaluated by pre- and post-test scores on several general mental abilities tests as well as the researcher's designed test. The results indicate that the experimental group not only scored significantly higher in the general mental ability test, but also on the measures of specific skills taught. It was concluded that, general and specific thinking and reasoning skills can be cultivated through stand alone thinking skills instruction.

This approach was also effective in developing creative thinking. For example, Ristow (1988) examined the effect of thinking skills instruction on grade three students' ability to think creatively. The treatment group was exposed to direct instruction of creative thinking skills by using the stand alone approach (30 minute sessions each week for six consecutive weeks). No treatment was given to the control group. The dependent variables were pre- and post-test measures of the Torrance Test of Creative Thinking (Torrance, 1984) which measures three sub-components of creativity; fluency, flexibility and originality. The treatment group showed significant improvement in two out of the three components of creativity; flexibility and originality. Although the length and duration of treatment was minimal, the result does suggest that certain aspects of creative thinking can be enhanced through direct instruction. In terms of students' critical thinking ability, significant, positive effects of direct instruction have been shown by Kolstad, Briggs and Hughes (1992), who conclude that direct instruction in critical thinking improved students' ability to think critically. Ristow (1988) and Kolstad, Briggs and Hughes (1992) provide additional support of the effectiveness of the direct approach in cognitive skills acquisition. In their review of 20 studies, McKeachie *et al.* (1987) synthesise three instructional variables that contribute to the development of critical thinking: student discussion, explicit emphasis on problem solving procedures, and explicit emphasis on methods to encourage development of metacognition.

A meta-analysis study of the effect of explicit critical thinking instruction conducted by Bangert-Drowns and Bankert (1990) also concludes similarly. They found that students in younger grades benefited more from critical thinking

instruction than did students in high school and college. The average effect size for elementary and junior high grades was .50 of a standard deviation and .21 of a standard deviation respectively. It was also found that students receiving instruction through an explicit approach performed half a standard deviation better than their uninstructed counterparts. No evidence was found that length of treatment is related to the effects of treatment.

However, this approach does not increase students' academic achievement. Johnson (1997) investigated the effect of general thinking skill instruction on elementary students' critical thinking ability as well as their writing performance. The results show that significant differences were found between critical thinking pre and post-test scores. However, in terms of overall effectiveness, the experimental group only shows slight difference from those in the control group. The result on the writing performance showed no significant difference between test time as well as across experimental groups.

More comprehensive studies on the effectiveness of direct instruction are reflected in Schoenfield (1982) and Robin and Mayer's (1993) studies where it was shown to improve cognitive skill acquisition and the transfer of skills across subject knowledge.

Schoenfield (1982) compares the effectiveness of the direct approach in problem solving skills to domain specific strategies on the acquisition and transfer of problem solving skills. By employing a pre- and post-test *quasi-experimental* control group design, college freshmen and sophomores enrolled in a Mathematics problem-solving course were divided into a treatment and control group. The treatment group was taught general problem solving strategies in small groups, with an emphasis placed on the process of solving problems and selecting appropriate strategies. The control group, on the other hand, was taught domain specific ways to solve problems without an emphasis on process and strategy selection; viz. the class time was used to learn and practise, structured, orderly ways to approach problems. Skill acquisition

was measured in both quantitative and qualitative ways. Quantitative assessment on skill acquisition was conducted by examining and comparing students' ability to generate, select, and pursue plausible approaches to mathematical problem solving. The qualitative assessment consisted of a *Likert-type* rating scale where students reacted to their own problem solving performance and described their own problem solving processes. In assessing transfer, pre- and post-test measures to rate and record students' ability to transfer problem-solving strategies to closely related problems, somewhat related problems, and unrelated problems were employed. Analysis of findings show that the experimental group not only demonstrates significant improvement in their problem solving skills, but is more organised in the way it approaches the problem. More importantly, this group of students also shows a significant improvement in terms of their ability to transfer the skills acquired not only to closely related problems and somewhat related problems, but also to highly unrelated problems. It can be concluded that general problem solving strategies can be successfully used to teach thinking strategies and this sort of instruction produced more transfer than domain specific thinking skill instruction.

By employing a true experiment research design, Robin and Mayer (1993) compared the effect of four instructional strategies on students' ability to acquire and transfer analogical reasoning skills. Subjects in this study were treated by computer simulation programme, which provides training on 20 practice analogies in one of four instructional methods: 1) schematic[7]/high road 2) schematic/low road, 3) nonschematic[8]/high road[9], and 4) nonschematic/low road[10]. At the end of the training, subjects were asked to solve new analogy problems of the same relational type (near or low road transfer), and take a recognition test using the terms learned in the previously presented analogies (recognition memory). Measures of students'

[7] Schematic instruction consisted of practice problems grouped by type and accompanied by direct instruction, which described the problem type.

[8] Non schematic instruction consisted of practice problems arranged in random order without a description of the problem type.

[9] High road instruction or problem utilises high cognitive load, which consisted of practice problems presented as an exercise without examples of the correct solutions.

[10] Low road instruction or problem utilises a low cognitive load, which consisted of worked-out examples that emphasised the formation of correct relational schemas.

error rates and response times were used to compare the effectiveness of each instructional method. The results indicate that schematic low road instruction was the best condition for learning problem solving initially and for transferring this knowledge to similar or "near-transfer" problems. However, there was no significant difference in the type of instruction for problems considered as "far transfer" and for measures of memory recognition. These results suggest that thinking skills are best learned when schema or problem types are identified and accompanied by direct instruction, the cognitive system is not overloaded, and there is an adequate amount of modelling and practice.

The embedded as opposed to stand alone approach seems to have a significant positive effect especially on students' academic achievement. For example, Worsham and Austin (1983) examined the effect of thinking skill instruction within a language Art programme on students' performance on the verbal portion of the Scholastic Aptitude Test. 139 students were sub-divided into treatment (87) and control groups (52). The former group was exposed to general thinking skills embedded within their daily English Language curriculum with specific focus being given on problem solving and reasoning processes, recognising point of view, and cognitive and metacognitive process. No treatment was given to the control group. The results show significant differences between the groups in all three elements of the verbal portion of the Scholastic Aptitude Test (vocabulary, reading score and total score of the verbal portion), suggesting that embedded thinking skill instruction enhances performance in the area of language.

The effect of an embedded approach within a college Geology course on student critical thinking ability as well as academic achievement was initiated by Crow and Hows (1985). By employing an experimental method, student were randomly divided into two groups; the treatment group used the regular Geology subject matter with logic and thinking skills embedded and the control group used the same subject matter in which neither logic nor thinking skills was taught. The results indicate that the treatment group not only demonstrated greater changes in their

critical thinking post-test scores, but also in their Geology achievement test. The author, besides arguing that embedding critical thinking skills in the content provides more structure to content and hence facilitates a deeper level of understanding (achievement test score), suggests that complex, critical thinking skills can only be grasped if only such skills are presented in a context familiar to the students. Such a finding is consistent with McKeachie *et al.* (1987) who emphasised that when critical thinking is embedded in content-specific material, its effects appeared to be significant on tests which require application of critical thinking to the content.

Baron (1990) examined the effect of thinking skills instruction embedded in a third grade Reading class on students' higher level thinking and reading attitude. 20 third graders were exposed to instruction on higher order questioning and prediction within a standard reading curriculum (embedded approach). Instruction lasted for 30 minutes each day for eight weeks. Besides pre- and post-test measures assessing thinking skills related to reading, differences in Reading attitude were also gauged. Significant difference was shown not only in terms of thinking skills acquired, but also Reading attitudes. This suggests that direct instruction using an embedded approach is effective not only in enhancing students' thinking skills particularly in performing questioning and prediction tasks, but also their attitudes towards Reading.

Collin (1991) examined the effect of embedded thinking skill instruction on students' Reading achievement, writing and thinking. Subjects were 168 middle schools students randomly assigned to experimental and control groups. The experimental groups received instruction in eight different kind of thinking skills: classification questions, pattern recognition, decision making, problem solving, metacognition, creative reasoning, innovative reasoning, and reasoning in groups and individually. These lessons were interspersed for 15 weeks (three days a week). The control group received a standard skills-oriented reading curriculum based on skills found in the Iowa Basic Skills Test. Three independent variables were used as a basis for comparison: the Iowa Test of Basic Skills for measuring scholastic achievement; a writing test used to measure both communication and the number and type of

thinking/reasoning skills exhibited by students; and self reports used to assess the transfer of thinking skills from school to real-life situations. The results showed that significant differences favouring the experimental groups on all the three dependent measures.

In the area of science education, one of the examples of the infusion approach has been demonstrated in Biology. Zohar, Weinberger and Tamir (1994) replicated Moll and Allen (1982), Novak and Dettloff (1989), Statkievicz and Allen (1983) studies by investigating the effect of content embedded critical thinking instruction in the field of Biology. The authors, guided by the preliminary study and findings of Zohar and Tamir (1993) a year earlier, measured the effectiveness of the programme by assessing the students' general reasoning abilities, academic achievement, and the application of subject specific or domain specific thinking skills instruction. This study employed an experimental method whereby the subjects (consisting of 678 seventh grade students) were randomly assigned experimental and control groups. While the control group continued with their daily Biology curriculum, the experimental group received extra instruction in seven subject-specific critical thinking skills embedded in their Biology classes, which lasted for 24-class periods. Dependent variables consisted of a standardised critical thinking test, and an achievement test to assess Biology knowledge. Additional information on the effectiveness of the programme was obtained through feedback on weekly reports, interviews and observations. The results indicate that the experimental group as compared to the control group scored significantly higher in the standardised critical thinking ability test, significantly outperformed the control group in subject specific thinking skills instructions and scored significantly higher than the control group on measures of Biology knowledge. These results seem to be consistent with a prior study conducted by the Zohar and Tamir (1993). Recently the effectiveness of the embedded as opposed to traditional approach was also measured by Kaplan (1997), and similarly, significantly positive effects were shown on the students' decision making ability.

To summarise, the content embedded approach of teaching thinking skills is not only effective in increasing students' academic achievement, but also provides an alternative path to the direct approach in the acquisition of cognitive skills (e.g. Baron, 1990; Kaplan, 1997). In addition, it also encourages transfer of skills across subject knowledge as empirically shown in Collin (1991), Zohar and Tamir (1993), Zohar, Weinberger and Tamir (1994) studies.

The immersion approach, however, is not as popular as the first two approaches discussed earlier. Its application is only shown by one study conducted by Riding and Powell (1987) who examined the effect of computer generated critical thinking activities on kindergarten children's critical thinking skills, and the extent to which transfer of this training occurred in the area of Reading and Mathematics. 64 five-year-old kindergarten children with varying abilities were divided into two groups. The experimental group received immersion critical thinking treatment consisting of 32 self-paced, computer presented thinking activities. The control group on the other hand used a similar amount of time to work on other curriculum-related tasks. The experimental period was 13-week periods. The experimental group demonstrated significant improvement on measures of critical thinking skills and achievement (particularly for the low achieving students). Nevertheless, when children's Mathematics progress was measured (60 questions covering variety of mathematics and numerical concepts), no significant difference was found. These results suggest that an immersion approach to thinking skills instruction only positively affect students' critical thinking skills, and that this effect appears to be the greatest for the low achiever readers.

Colledge (1993) investigated the effectiveness of the immersion approach as opposed to embedded approach in cultivating students' critical thinking ability. Students' critical thinking skill was measured by the Ennis-Weir Critical Thinking Essay Test (Ennis and Weir, 1985). Two heterogeneous groups; one with 22 students who received embedded thinking skills instruction within English Language and social studies classes, while another 27 group of students used an immersion

approach. Based upon mean difference between the pre- and post-test score, the results indicated that there was a significant growth in measures of critical thinking skills for both approaches, but in terms of effectiveness, both techniques seemed to be equally effective.

Another comparative analysis between the two thinking skills approach (embedded and immersion) on student critical thinking skills was employed by Jones (1993). In this two experimental and one control group design, experimental group one was exposed to critical thinking instruction via embedded approach. In this approach, students received instruction and employed metacognitive rehearsal in the use of particular thinking skills and activities. Experimental group two used an immersion approach. In this case, students were guided and given independent practice in the use of various thinking skills and activities, however, direct instruction and metacognitive rehearsal were omitted. The control group, on the other hand, used traditional textbook methods and activities. The measurement of students' critical thinking ability was made by using the Cornell Critical Thinking Test, Level X (Ennis and Millman, 1985). The result indicated that both experimental groups scored significantly higher on the deduction and induction sub-tests portions of the CCTT, Level X post-test than the control group. However, between the two experimental groups, the immersion approach demonstrated a significant increase between the pre- and post-test score on deduction skill. In general, the results concluded that both embedded and immersion instruction have some positive effect on students' ability to perform a standardised critical thinking test, with the immersion approach perhaps showing some advantage.

3.6. SUMMARY

The first two ambivalent approaches (direct and embedded) receive more attention in the thinking skill literature in general and critical thinking skill literature in particular. These two approaches are commonly known as the *skill* versus *content* oriented views of teaching thinking (Yildirim, 1994). In the area of science

education, such an issue evokes controversy between enhancing thinking skills by emphasising general *strategies* or *domain specific* skills (Niaz, 1995). Findings from the research highlighted in the previous section reveal that direct instruction is not only effective in nurturing specific thinking skills strategy but also encourages transfer of skills across the curriculum. On the other hand, the effectiveness of the content embedded approach is not only in cultivating thinking skills in students, but also as an appropriate means in upgrading their academic performance.

Analysis of the specific objectives listed in the Syllabus Specification Guidebooks of the ISSSC conducted previously by the researcher (1995) indicates that the acquisition of thinking and problem solving skills is emphasised. Most of the experimental procedures that lead to the acquisition of scientific concepts, principles and law stress the importance of scientific skills; i.e. science process (e.g. hypothesising, predicting, interpreting, drawing conclusion etc) and manipulative skills (e.g. manipulates laboratory equipment needed in solving the problem under investigation). However, since there is no provision of time allocated for the teaching of such skills, it is argued that the flexible nature of the embedded approach which can be integrated into the subject will satisfy the demand of the existing Integrated Secondary School Science Curriculum (ISSSC) effectively.

4

INSTRUMENTATION AND RESEARCH DESIGN

4.1. INTRODUCTION

Guided by the researcher's conceptualisation of research as a systematic hypothetico-deductive method of scientific enquiry, the methodological procedures in this study started with the presentation of the *research problem*. Within the context of the problem, the *aims and objectives* are outlined, a *research design* is developed, together with the relevant research *hypotheses*. The "intact nature" of the samples used in this study rationalises the selection of the *quasi-experimental* research design from the wide arrays of research designs available. Such a design is perceived as the most appropriate tool in utilising educational research as an instrument in social engineering especially when "randomised treatments are not possible" (Campbell, 1969; p. 411)

This chapter mainly deals with the various *instruments* used in carrying out the research design. Besides the three standardised instruments (the Cornell Critical Thinking Test, Level X (CCTT, Level X), the California Critical Thinking Disposition Inventory (CCTDI) and the Science Teaching Observation Schedule (STOS)), the researcher also developed two other instruments; the instructional material (the module) and the evaluation test. The module provides an alternative means to the lecturing mode of instruction in delivering the pedagogical content knowledge of how to embed critical thinking in the science instruction. The evaluation test is designed to measure student teachers' mastery of the pedagogical content knowledge. Throughout the course of this chapter, extensive reviews of the *reliability and validity* of the instruments will be presented together information gathered from the *pilot study*. As in many other research methodology presentations, this chapter ends with *procedures of data collection* and the *statistical analysis* involved in testing the hypotheses.

4.2. THE INSTRUMENTS

4.2.1. The Cornell Critical Thinking Test (CCTT), Level X

The Cornell Critical Thinking Test (CCTT), Level X consists of 71-multiple choice items sub-divided into four sections: i) Inductive Inference; ii) Credibility of Sources and Observation; iii) Deduction; and iv) Assumption Identification. This test provides a contextual situation in Nicoma, a newly discovered planet that has just been landed on by a group of explorers from Earth. The mission of the explorers is to search for a pioneer group of explorers who set foot on Nicoma two years earlier (see APPENDIX A). In answering this test, the examinees are asked to imagine that they are members of the search party and their task in every section is summarised in TABLE 4.1.

TABLE 4.1

CORNELL CRITICAL THINKING TEST, LEVEL X

Section I:	**Inductive Inference** Require evaluation of whether a fact, supports, not necessarily proves, a hypothesis. Essentially, the tasks involve determination of whether pieces of information discovered by the search party are i) evidence for, ii) evidence against, or iii) neither evidence for nor against the idea that the members of the first group are all dead;
Section II:	**Credibility of Sources and Observation** Statements and reports made by the search party are proffered in pairs and judgements were required to determine which, if either, of the statements is more believable;
Section III:	**Deductive Inference** The explorers reasoning suggestions and expectations are expounded, and in each case the examinees are asked to select the probability which follows the information given; and
Section IV:	**Assumptions Identification** Require identification or judgement of what is assumed in an argument. Mainly the tasks involved are to identify what is probably taken for granted in the reasoning of characters in the story.

Although aspects of critical thinking are listed separately as shown in TABLE 4.1, there is considerable overlap and interdependence among them in the actual process of critical thinking. For instance, prediction to test a hypothesis or inductive inference would at least to some degree require deductive skills, and observation statements made by a person would also require skills in testing a hypothesis (inductive skills), besides assumption and credibility skills. Since it is theoretically difficult to secure an independent parts score, critical thinking ability as measured by the CCTT, Level X used in this study is homogenous, and the score for every section is accumulated as a single score.

The use of the CCTT, Level X in this study is justified for several reasons. First, the conception of critical thinking used in this study is based primarily on the theories promoted by Robert Ennis, the developer of the CCTT, Level X. It is argued that the CCTT, Level X is a more inclusive test for this study since "there are some aspects of critical thinking in the Cornell test which are not evaluated under the Watson–Glaser test" (Norris, 1986; p.138). Second, although the CCTT, Level X is not as popular as the Watson-Glaser Critical Thinking Appraisal Test, when comparison in terms of validity and reliability were made between the two, no statistically significance differences were shown (Modjeski and Michael, 1983). And finally the researcher found that the CCTT, Level X was not only easier to understand by the target audiences, but was also easier in terms of test administration and scoring procedures.

4.2.1.1. Reliability of the Cornell Critical Thinking Test (CCTT), Level X.

Reliability refers to the degree of consistency or precision of test scores from one occasion to another (Guilford and Fruchter 1978; Thorndike, 1988; Youngman, 1979). Anastasi (1982) regards reliability estimates as a "yardstick" to measure the degree to which individual differences are attributable to "true" differences in the characteristics under consideration and the extent to which they are attributable to chance errors. To put it in more technical terms, measuring test reliability makes it

possible to estimate what proportion of the total variance of test scores is error variance. For example: a reliability coefficient of .74 signifies that 74% of the variance in the test scores depends on true variance in the trait measured, and the remaining 26% depend on the error variance.

There are four commonly used methods of estimating a reliability coefficient: test-retest, alternative-form, split half and internal consistency. The preference of a reliability estimate depends mostly on the type of test, the meaning of the statistics and the purpose for which the statistics will be used (Guilford and Fruchter, 1978). The homogeneity of the CCTT, Level X in which the whole test measures the same abilities, and the fact that it is a power test (i.e. all examinees will manage to answer every item within the time frame of test administration) justifies the use of internal consistency as a measure of reliability (Thorndike, 1988). Additionally, this method of estimating reliability only requires a single test administration as opposed to test-retest and alternate-form methods, thus co-operation of examinees is required for only a single period of testing. Internal consistency as a reliability index overcomes the drawback of constructing two alternative parallel tests as in the alternative-form method. Not only that, the possibility of producing different reliability estimates even though the same items are administered to the same individuals at the same time as in the split-half method would also be avoided (Carmines and Zeller, 1979; Jones, 1971; Tuckman 1975).

Essentially, internal consistency reliability deals with the consistency of performances on one group of individuals across the items on a single measure. Among the three common procedures for estimating the internal consistency are the Spearman-Brown Prophecy Formula C (Brown, 1910; Spearman, 1910), Cronbach Alpha (Cronbach, 1951) and the Kuder-Richardson Formula (Kuder-Richardson, 1937). In this study, the internal consistency was computed by means of a pilot study by employing the Kuder-Richardon Formula 21 (KR_{21}). When comparison is made between the three methods, it shows that KR_{21} is a derivation of Cronbach's

coefficient alpha equation by simply reducing the scores of all items to either 0 (incorrect score) or 1 (correct score). KR_{21} takes the form of:

$$\text{Reliability} = \frac{n}{n-1}\left\{1 - \frac{\Sigma n \cdot \bar{p} \cdot \bar{q}}{s_t^2}\right\}$$

where $\bar{p}$ is the mean percent of the correct responses, and $\bar{q}$ is the mean percent of the incorrect responses. From the equation, it seems that KR_{21} provides a quick and convenient way of estimating reliability because only information about the number of items (n), and their means and the standard deviations are required.

By following the basic procedural requirements of KR_{21}, the score of every item is changed into two dichotomous scores of 0 and 1 which represent the incorrect score and correct score respectively. Estimating reliability coefficients should be accompanied by a full description of the type of group on which it was determined. In the pilot study undertaken, the sample is the Diploma of Education science student teachers at the Universiti Kebangsaan Malaysia (UKM). This group of student teachers could be conceptualised as moderately able students, possessing the same background knowledge in teaching and learning, with ages ranging from 23 to 28 years old. Such fulfilment of sample characteristics is crucial in the reliability coefficient estimations as Anastasi (1982) reminds:

> "A desirable and growing practice in test construction is to fractionate the standardisation sample into more homogeneous subgroups, with regards to sex, age, grade level...and to report separate reliability coefficients for each subgroup. Under these conditions, the reliability coefficients are more likely to be applicable to the samples with which the test is to be measured in the actual practice"
>
> (Anastasi, 1982; p.125)

Anastasi's (1982) recommendation of sample homogeneity necessitates crucial consideration of sample variability and ability level in addition to test items of homogeneity in estimating the reliability of a test (Livingstone, 1988).

The computed internal consistency in the pilot study is .77, which means 77% of the variance in the test scores depend on true variance in the trait measured, and that the error variance only contributes 23% of the true variance. The relatively high value of KR_{21} indicates that the effect of any irrelevant conditions, which deviates from the purpose of the test, is relatively low (23%). Moreover, when this value is compared with the standardised values (within the same sample variability and ability level) its value also falls within the range of .67 and .86 as recommended by the publisher (Ennis, Millman and Tomko, 1985). Therefore, as far as homogeneity in both the sample and the test items are concerned, the reliability index provided by KR_{21} indicates of the suitability of the CCTT, Level X.

4.2.1.2. Validity of the Cornell Critical Thinking Test (CCTT), Level X.

Validity concerns what the test measures as well as what can be inferred from the test score. The importance of validity in test construction is stressed by Anastasi (1950) who insists that traits measured by a given test can only be defined through an examination of the objective sources of information and empirical operations utilised in establishing its validity. Validity must be established, with reference to the particular use for which the test is considered (Anatasi, 1982; Youngman, 1979; Zeller, 1988). An analytical review of validation methodology reveals that the most fundamental procedure is probing the relationship between performance on the test and other independently observable facts (e.g. sex, socio-economic status, and parental educational level) about the behavioural characteristics under consideration. There are numerous methods of establishing validity, and these can be classified into three fundamental categories: content, criterion-related and construct validity (American Psychological Association, 1974).

The choice of validation procedures will depend on the purpose of the test scores. The same test, when employed for different purposes should be validated in different ways. The purpose of the CCTT, Level X score in this study is to measure quantitative critical thinking skills as well as to predict the student teachers' attitude

towards critical thinking. Hence, construct as opposed to content or criterion–related validity would seem most apposite. Inevitably, construct validity also includes content and criterion reliability, as construct validity is a comprehensive concept (Anastasi, 1982). Nunally (1967) and Messick (1980) both insist that construct validity should be the overriding concern in test validation. It could be argued that although test scores may vary in range and generalisability with regards to behaviour domains, cultural settings and ethical values, its interpretation would be primarily based on the construct being measured.

The first step in examining construct validity of the CCTT, Level X instrument is to employ age differentiation, in which the test performance is checked against chronological age to determine whether the test scores show a progressive increase with advancing age. As advocated by the developmental psychologists (e.g. Piaget 1964) and as indicated in Binet's concept of an age scale of intelligence; viz. intelligence increases with age, at least until maturity, the test is justified as valid if it demonstrates an increase in ability as the maturity increases. The User Norm Information of the CCTT, Level X accumulated through extensive studies starting from the 1960's through early 1980's indicates that the score of the CCTT, Level X is strongly correlated with age (Ennis, Millman and Tomko, 1985). Feely (1975), Grandy (1993), and Hill (1995) also show recent empirical evidence on the relationship between critical thinking and chronological age. However, it should be borne in mind that validating a criterion by measuring the increment of such behaviour with chronological age would be influenced by different cultural backgrounds since

> "Different cultures may stimulate and foster the development of dissimilar behaviour characteristics...it cannot be assumed that the criterion of age differentiation is a universal one. Like other criteria, it is circumscribed by the particular cultural setting in which it is derived"
>
> (Anastasi, 1982; p.147)

Thus, satisfactory fulfilment of age differentiation could not be accepted as the sole justification of construct validity. It would also require examination of the test correlation with other test batteries in ensuring that the test is relatively free from

other factors such as the cultural factors (Anastasi, 1982; Ennis, Millman and Tomko, 1985).

The correlational use of the CCTT, Level X is reflected in Feely's (1975) study. The findings showed that there exists a significant predictive relationship between critical thinking ability and ability to use evidence. In addition, results from this study also indicated a positive, significant relationship between critical thinking ability and verbal ability, socio-economic status and educational expectation. Feely's (1975) findings seem to support the correlational data provided by Ennis, Millman and Tomko (1985) especially with respect to educational expectation, whose 'r' values are between .40 and .74.

Grandy (1993) explored the relationship between critical thinking ability as measured by the CCTT, level X and the assessment of intelligent behaviour. The outcome of the study not only found a positive, significant relationship between the two variables, but the latter was also shown to be a good predictor of the former (a regression analysis was employed on the data). Besides a predictive relationship, the CCTT, Level X has also been used in associative studies. Hill (1995) conducted a descriptive, cross-sectional approach by comparing the associative relationship between the critical thinking skills of first semester freshmen and last semester seniors and the development of academic, personal and moral domains. Two types of academic, personal and moral traits were investigated; viz. measured and perceived. While the measured academic data were obtained by comparing the students' Cumulative Grade Point Average (CGPA), their personal and moral domains were measured by Robert Kegan's Subject-Object Interview and Lawrence Kohlberg's Moral Judgement Interview respectively. The perceived data on these three domains were gathered through extensive open-ended interviews. In this study, the construct validity of the CCTT, Level X is shown to be high since the critical thinking ability as measured in this test is positively and significantly associated both with the measured and perceived academic, personal and moral domains. In addition, as also shown in several previous studies (e.g. Feely, 1975; Ennis, Millman and Tomko,

1985) Hill too found that there were no gender differences in the critical thinking ability.

The direct use of the CCTT, Level X in correlational studies demonstrates another aspect of construct validity, which is described by Campbell and Fiske (1959) as "convergent and discriminant" validation. Correlation of the CCTT, Level X with subsequent scores in academic, personal and moral development as shown in Hill's (1995) study is one example of convergent validity. On the other hand, discriminant validity is illustrated by insignificant correlation of the same test with gender. Another evidence of discriminant validation of the CCTT, Level X is shown by Gilbert's (1993) study in which a weak inverse relationship between the critical thinking skills and the current practice of teaching critical thinking was detected. By convergent and discriminant validation, high and low correlation between the CCTT, Level X instrument with other variables with which it should theoretically correlate or differ is substantiated.

Besides age differentiation and correlational studies that may involve associative and predictive validity (see preceding paragraphs), construct validity can also be demonstrated through experimental studies. An examination of experimental studies finds that, in most cases the critical thinking ability as measured by the CCTT, Level X instrument was used either as an independent variable to evaluate the effectiveness of a specific learning programme or a specific learning strategy.

An example of the use of the CCTT, Level X instrument in evaluating the effectiveness of a specific learning programme shows that the common experimental design applied in this former experimental approach is to use the CCTT, Level X as a prime measuring device in testing the treatment effect. Clay (1976), for example, found that a structured Biology programme was significantly better than an independent study Biology programme in cultivating students' critical thinking ability. In investigating which approach of teaching thinking skills is the most effective in nurturing student critical thinking ability, Jones (1993) employed two

experimental groups and one control group design. Both the experimental groups received instruction through an immersion and embedded approach. Subjects were given the CCTT, Level X as a pre-test and post-test measure in order to compare the effectiveness of the two approaches. After ten weeks on intervention it was found that both experimental approaches had made a significant impact on the students' critical thinking ability especially in terms of their ability to make inductive and deductive inference. When comparison was made between the experimental approaches, Jones (1993) found that the immersion[11] teaching approach had managed to demonstrate a statistically significant increase between the pre-test and post-test critical thinking ability compared to the embedded or infusion[12] approach, particularly in the deductive section as measured in the CCTT, Level X.

In the latter approach, the critical thinking ability, together with several other indicants (e.g. attitudes, self-concepts, and achievement) was measured in evaluating the effectiveness of certain teaching strategies. Winocur (1981) was able to show that reading remediation strategy which emphasised critical thinking skills (according to Ennis's model of critical thinking) when applied to high school students was an effective way of improving not only students' reading comprehension and proficiency, but also their critical thinking ability. However, a reverse effect was demonstrated when the enquiry-related strategies were employed in social studies disciplines. As shown by Blanton (1988) this method of teaching was ineffective in developing student thinking skills as measured by the CCTT, Level X, self-concept as well as their attitudes towards subject matter.

When similar experimental approaches were applied at the lower school level, Rolen (1990) found that a direct instructional approach to teaching critical thinking did not have a significant impact on the students' critical thinking ability. There was

[11] Immersion approach: the critical thinking principles embedded within the subject matter instruction are not made explicit

[12] Infusion approach: the critical thinking principles embedded within the subject matter instruction are made explicit.

also insignificant impact shown on their achievement score as well as content retention. Although the period of treatment (five weeks) could be argued to be a contributive factor, Cohen (1972) showed that teachers' questioning behaviour had a negligible effect on pupil critical thinking ability although the treatment given lasted for one year.

From this discussion it can be concluded that empirical data derived from age differentiation studies, correlational studies, convergent and discrimination validation studies and experimental intervention studies all provide evidence of the construct validity of the CCTT, Level X instrument. When this evidence is added on to the empirical evidence provided by the publisher, a strong case for the construct validity of the CCTT, Level X instrument is provided.

4.2.1.3. Item Analysis as a Means of Gauging Index Discrimination and Item Difficulty

Item analysis not only gives an indication of the quality of items, but also enables a differentiation between the better and the poorer items to be made. Item analysis is performed for two main reasons; to measure index discrimination and item difficulty (Anastasi, 1982; Guilford and Fruchter, 1979; Youngman, 1979; Wood, 1988). Index discrimination refers to the degree to which an item differentiates correctly among examinees in the behaviour that the test is designed to measure. Obviously, this method allows comparison between those who perform well on the whole test and those who do poorly. The recommended portions are the top and bottom 27% of the tested population (D'Agostino and Cureton, 1975; Wood, 1988). An item that discriminates perfectly between the best and worst examinees will score +1. An item, which does not discriminate at all (i.e. the same number in both ability groups gets it right or wrong) will score zero. An item, which favours the lower group, will produce a negative result. Item difficulty of a test is "the percentage of persons who answer it correctly". The higher (above 73%) or the lower (below 27%) index difficulty means that the item is relatively easy or difficult and

henceforth not discriminating well. Likewise, if an item is answered correctly by 100% or 0% examinees, it has no differentiating or discriminating powers.

Index difficulty and item discrimination of the CCTT, Level X is gauged by allocating a score of each student teacher of either 1 (correct answer) or 0 (wrong answer). Under the assumption that the examinee that does not know the right answer makes guesses completely at random from among the alternatives, item difficulty (P) is computed by applying the following formula:

$$P = \frac{R}{T} \times 100\%$$

where:

P : the percentage of examinees who answered the item correctly

R: the number of examinees who answered item correctly

T: total number of examinees tested

From the index difficulty analysis of the CCTT, Level X, it was found that almost 91.5% of the items have an index difficulty of more than 20%. The highest index difficulty is 87% (Q65) and none of the item has index difficulty of 90% or more. From the obtained values of the index difficulty of the 71 items, the index difficulty of the overall CCTT, Level X is determined computing the mean index difficulty of the 71 items. The index difficulty of the CCTT, Level X as tested with the pilot study's respondents (n = 50) is .50, which implies that the test is neither too difficult, nor too easy. Such a difficulty level also shows that the CCTT, Level X instrument is suitable to be given to the science student teachers in this study. Additionally, the value also falls within the range (.50 to .65) as previously tested by Ennis, Millman and Tomko (1985).

The index difficulty is always used with an index discrimination value. Together the two indicate the discrimination power of a test. As highlighted in the introductory section, once the response proportions in the high group, P_H and

proportions in low group, P_L have been computed, index discrimination is obtained from their difference:

$$D = P_H - P_L$$

A better guide to discrimination is offered by using the *point biseral* correlation, which is obtained by computing the correlation between an item score and the total score for an individual (Anastasi, 1982; Guliford and Fruchter, 1979; Youngman, 1975; Wood, 1988). *Point biseral* correlation coefficients show 43 (60%) of the items have an index discrimination above the acceptance limit of 0.2 (Nunally, 1967). Amongst those items, 9 items have an index discrimination of above .40, 16 items fall within the range .30 and .39 and 18 items have index discrimination between the range of .20 and .29. 16 of the items seem to favour the lower group, which is shown by the negative index discrimination value. The overalls mean index discrimination is .32. Previously, as indicated in the user manual, the index discrimination of the test is between .15 to .36 (Ennis, Millman and Tomko, 1985).

It seems that the CCTT, Level X instrument when tested with the student teachers involved in the pilot study is a valid, reliable and appropriate instrument for measuring critical thinking skills. The data presented to support the use and interpretation of the instrument are largely favourable and comparable with other studies in the field which recommend the CCTT, Level X as the best available instrument for measuring adult critical thinking skills. The results presented here indicated that it is also a suitable instrument for use in the Malaysian context.

4.2.2. The California Critical Thinking Disposition Inventory (CCTDI)

The CCTDI is a carefully crafted instrument specifically designed to measure critical thinking affective and attitudinal dimensions; viz. opinions, beliefs, and attitudes in relation to critical thinking. The conceptual development of the CCTDI

began in 1990 and is rooted in the conceptualisation of critical thinking yielded through cross-disciplinary experts' participation in the so-called Delphi Project. The significance of critical thinking dispositions is reflected by the extended consensus among the Delphi's participants to go beyond identifying a core set of cognitive skills and sub-skills to the articulation of a description of the ideal critical thinker. These efforts were triggered by the experts' insistence that critical thinking per *se* is only one form of cognition and the teaching of critical thinking would be fruitless without an appreciation of the character profile of the kind of individuals one was trying to nurture. As consensus was reached, the constellation of attitudes of the ideal critical thinker surfaced as:

> "...habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgements, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit"
> (APA, 1990; p.3)

The expert consensus cited above is discipline neutral and encompasses a generalisable description of the ideal critical thinker in a multiple context (Facione, 1992). More importantly, it captures what some have called "the critical spirit"– a habit of mind which is more commonly referred to as the disposition to use critical thinking in one's personal and civic affairs (Brown and Kelly, 1990; Carter-Wells, 1992; Chafee, 1992; Dewey, 1933; Ennis, 1985; 1987; Glaser 1984; Gray, 1993; Hudgins, 1977; Jones, 1993; Mayfield, 1993; Meleis, 1988; Meyers, 1986; Passmore, 1972; Paul, 1984; 1990; Scheffler, 1973; Siegel, 1988).

At the outset of the development of the CCTDI instrument, the conceptual framework of the notion of a disposition towards critical thinking remained largely within the realm of theoretical speculation, working assumptions, anecdotal observations and pedagogical discussions rather than the subject of scientific investigations (Jones, 1993; Norris and Ennis, 1989). An empirical approach to the exploration of a disposition to critical thinking was constrained by the dearth of

instruments designed to measure it. Facione and Facione (1992) was able to refine empirical derivation of the APA Delphi conceptualisation of critical thinking disposition. By employing the iterative empirical method, critical thinking disposition constructs are derived and the variables involved in constituting the constructs are then arranged as items in the California Critical Thinking Disposition Inventory (CCTDI).

The CCTDI is composed of 75 items (see APPENDIX B) and generates eight scores: a score on each of the seven scales (**T**ruth Seeking, **O**pen Mindedness, **A**nalyticity, **S**ystematicity, Self **C**onfidence, **I**nquisitiveness, and **M**aturity) and the overall score of the critical thinking disposition (derived from mathematically equal contributions from each scale). Every scale is composed of nine to twelve items, and is interspersed throughout the instrument in order to decrease the likelihood of giving socially desirable responses (Facione and Facione, 1992). Detailed definitions and examples of items on each scale are found in APPENDIX C. Responses are recorded using a six-point Likert scales ranging from strongly agree to strongly disagree. For each item, to agree (or disagree) is consonant with (or in opposition) to a recognised critical thinking dispositional attribute. The 75 CCTDI statements prompt familiar opinions, beliefs, values, expectations and perceptions. Phrased in standard English, they use no technical vocabulary or critical thinking jargon and no college content level is presumed.

In order to test the reliability of the CCTDI, a pilot study involving 50 undergraduate engineering students was conducted. A database consisting of a subject by item matrix was produced. As Dunn-Runkin (1988) has suggested, the operational procedures of attitudinal measurement, where unit values are assigned according to Likert scaling warrants reliability and item analysis of the Bahasa Melayu (Malay Language) version of the CCTDI.

4.2.2.1 Reliability of the CCTDI

Unlike the CCTT Level X, the CCTDI involves more than simply correct or wrong answers. The reliability of the CCTDI was computed using the Cronbach Alpha (Cronbach, 1951) procedure. The suitability of Cronbach's formulation as opposed to KR_{21} in treating the CCTDI data is due to the general application requirement of this formula. It could be applied not only to dichotomous but also to items where a number of possible scores is made (Guilford and Fruchter, 1978; Youngman, 1979). The coefficient α (alpha) is computed by substituting the Σpq in KR_{21} formula with ΣV_I where V_I is the variance of each item. When the value of the overall test variance V_t is known, the consistency of performance across n items is computed by applying the Cronbach's formulation below:

$$\alpha = \frac{n}{n-1}\left\{1 - \frac{\Sigma V_I}{V_t}\right\}$$

As shown in TABLE 4.2, the coefficient alpha ranged from .40 to .81 for the sub-scales and .85 for the overall score. It should be noted that in this preliminary study, the Bahasa Melayu target language version of the CCTDI is treated like a new instrument and an alpha of .70 is considered adequate (Nunally and Bernstein, (1994). The computed alpha for the overall CCTDI score of .88 falls 25.7% beyond the predetermined value and thus signifies the internal consistency reliability. Across the sub-scales, only two had an internal consistency coefficient greater than .70 (**T**ruth Seeking = .71; Self **C**onfidence = .81).

One reason, which could account for a low internal consistency index (<. 5) is the homogeneity of the sample and test size (Anastasi, 1982; Cronbach, 1951; Youngman, 1979). The **T**ruth Seeking sub-scale, where alpha value exceeds the predetermined point of .70, was calculated on the basis of the same number of items as the **O**pen Mindedness score (α = .42). In fact the highest alpha value is shown by the test with the lowest number of items (Self **C**onfidence; α = .81). Therefore, the

number of items on the sub-scales does not explain the relatively low reliability. Another factor, which triggers low internal consistency, is the low variability of the test scores. An increase in score variability (indicated by the score variance) will generate increased internal consistency reliability. From the results, the lack of variability among the scores appears in all the sub-scales. Consequently, it could be concluded that lack of score variability, resulting from sample homogeneity, is the reason for the low internal consistency reliability.

TABLE 4.2

COEFFICIENT ALPHA FOR THE SEVEN SUB-SCALES AND OVERALL SCORE OF THE BAHASA MELAYU CCTDI

SCALE NAME	*NUMBER OF ITEMS*	*ALPHA RELIABILITY (α)*
Truth Seeking	12	.71
Open Mindedness	12	.42
Analyticity	11	.40
Systematicity	11	.57
Self Confidence	9	.81
Inquisitiveness	10	.52
Maturity	10	.63
CCTDI Total Score	75	**.88**

4.2.2.2 Criterion and Construct Validity

In the past few years, the CCTDI has been used extensively in correlational studies. Mainly these studies employed a multi-group research design (contrasted group method) in which the participants were categorically grouped according to their level of educational experience. In most cases, the disposition towards critical thinking was measured alongside the measurement of critical thinking skills and the relationship between the two scores was probed by means of correlation analysis. Literature analyses also show that these studies quantified the effect of several other demographic variables such as gender, age, and major of specialisation upon the CCTDI score. As suggested by Anastasi (1982), the information gathered from these studies could be cited as evidence of the effectiveness of the CCTDI in predicting an individual's behaviour in a specified situation; viz. criterion validity.

Bower (1995) investigated the differences of the critical thinking skills and critical thinking dispositions in 335 nursing students from four groups: freshmen, sophomores, juniors and seniors. The CCTDI and the California Critical Thinking Skills Test (CCTST) were utilised to determine if there were significant differences in the CT skills and dispositions among those four class levels. Age and gender variability and its impact on the CCTDI and CCTST scores were also investigated. It was found that all three categorical factors had made a significant contribution towards the attitudinal dimension of critical thinking as measured by the CCTDI. Age and gender on the other hand, only affected critical thinking ability, and no significant influence of class level was detected. Bower's (1995) findings were replicated by Doas (1996) who also found that class level (freshman generic, senior generic, RN – BSN first year, and RN – BSN second year) had a significant effect on the critical thinking dispositions as measured by the CCTDI.

Besides being used as an instrument by which a comparison of students' attitudes could be quantified, the CCTDI can also be used as a means of critical thinking attitudinal differentiation between students and faculty members. Lacey

(1996) investigated the critical thinking skills and disposition of three different groups; associate degree, baccalaureate nursing students, and nursing faculty members. A comparison of the CT skills and dispositions between the two groups of students (associate degree vs. baccalaureate nursing students) and between students and the faculty members was achieved by two-stage t-test analyses. No significant statistical difference was shown on both CT skills and attitudinal dimensions. However, significant differences were shown when comparisons were made between the students and the faculty members. Analysis of variance and the *post hoc* confirmatory analysis showed that CT skills and dispositions significantly correspond to the group classification with the highest score demonstrated by faculty members.

Another important contribution towards an understanding of the validity of the CCTDI as an attitude measurement instrument has been shown by Walsh (1996). In an exploratory study, the effect of major and gender on the disposition towards critical thinking as measured by the CCTDI was explored and the stability of the factor structure of the CCTDI across those variables was also examined. The examination of a 499 X 75 CCTDI database, (constituting data from 499 respondents on the 75 CCTDI items) revealed significant difference on the **T**ruth Seeking, **O**pen Mindedness, Self **C**onfidence, **I**nquisitiveness, **M**aturity and total CCTDI dispositions across major of specialisation. Further multivariate analyses of covariance showed significant main effects across gender on the **O**pen Mindedness and **M**aturity scale. The main effect of major of specialisation was shown in the **T**ruth Seeking, **O**pen Mindedness, Self **C**onfidence, **I**nquisitiveness and **M**aturity sub-scales. The principal components confirmatory factor analyses suggest that the CCTDI was capable of discerning differences among different majors and genders. The data suggested that although further research is needed to replace unstable construct combinations, which are built into some items of this instrument, the CCTDI as a whole is stable across gender and major of specialisation

As advocated by Sternberg and Weil (1980), when an individual's performance on a particular test is connected with several basic elementary cognitive

processes, not only the diagnostic use of that test is enhanced, but it also strengthens and enriches our understanding of what the test actually measures (Anatasi, 1982). In other words, information derived from the field of cognitive psychology could be used as indices of construct validation, which in turn facilitate the tailoring of training programs to the individual's needs. Thus, in the following, the value of the CCTDI demonstrated in cognitive psychology research can legitimately be perceived as an index of construct validation of the CCTDI.

Research concerning personality attributes in relation to motivation and cognitive strategies in problem solving and decision making hypothetically suggest that a significant relationship can be predicted to exist between a disposition towards critical thinking and the construct of "openness to experience" and "ego resiliency". Openness to experience covers a broad dimension of human personality, which is manifested by rich:

> "...aesthetic sensitivity, awareness of inner feelings, need for variety in actions intellectual curiosity, and liberal value systems"
>
> (McCrae and Costa, 1987; p.145)

Ego resiliency on the other hand, refers to a person's ability to alter their modal perceptual and behavioural functioning to adapt to situational constraints (Block and Block, 1980).

The hypothetical relationships between the dispositions towards critical thinking as measured by the CCTDI with openness to experience and ego resiliency have been empirically tested by Sánchez (1993). It was found that five out of the seven sub-scales of the CCTDI show significant correlation with the openness to experience construct (**I**nquisitiveness: r =. 37; **O**pen Mindedness: r =. 33; **M**aturity: r = .30; **T**ruth Seeking: r = .27; Self **C**onfidence: r = .25). When the correlation of the CCTDI to the ego resiliency constructs was measured, all the seven sub-scales of the CCTDI appear to have a significant positive relationship, especially the **S**ystematicity (r =. 47), **T**ruth Seeking (r =. 41) and **I**nquisitiveness (r = .39) scales. From the magnitudes of the correlation coefficients it could be implied that ego resiliency was

most highly associated with focused diligence, objectivity and intellectual curiosity in critical thinking cognitive style.

The empirical evidence of a significant relationship between the CCTDI scales and the openness to experience construct is consistent with preliminary confirmatory factor analytic studies by Tellegen (1981) who suggests that the CCTDI is measuring a similar construct as openness to experience and cognitive engagement with one's surroundings. The validity of the CCTDI is also reflected in Hicks (1997) studies, where the score of CCTDI correlates with the consistency of clinical decision making of low and high complexity tasks. Sánchez (1993) and more recently Hicks (1997), justified the validity of the CCTDI in measuring intellectual curiosity, as well as active engagement in one's surroundings.

4.2.2.3 Item Analysis

In order to reveal inconsistencies, if any exist, and to elicit subjects' performances of every item, an item analysis was performed (Youngman, 1979). The mean score on every item indicates the index of difficulty, and the correlation of items with the total score (*point-biseral correlation*) acts as the discrimination index. The means of items ranged from 2.18 to 5.48, with the range of standard deviation between .80 and 1.67. The overall mean of the 75 items was 3.87. In Likert scaling, the interval between units is presumed equal and the predetermined mean falls within the range of 3.45 and 3.55 (3.5 ±. 05). The overall mean value is higher than the acceptance value (3.5) and thus permits all items to be retained.

From the same analysis, index discriminations are calculated using the corrected item – total correlation (*point-biseral correlation)*. The lowest index discrimination value is -. 05, but the maximum value is relatively high (.67). In order to maintain consistency among the items, items with low index discriminations were further examined to determine whether they should be retained or discarded. The minimum acceptance value is .20. However, as Yeh (1996) suggested when the data

is garnered from a homogenous sample, the value could be reduced to .10. The examination of index discrimination was executed recurringly until no index discrimination was less than .10. Eventually, it was found that item deletion did not effectively improve the reliability of the sub-scales with the result that no item was discarded from the sub-scales.

4.2.3 The Evaluation Test

The usual definition of an evaluation test holds for this study. It is a test which is specifically designed to measure the effect of a programme of instruction (in this case self-instructed vs. lecture instructed) (Anastasi, 1982) as well as the attainment of individuals (Thorndike and Hagen, 1977). Thus, the operational function of the evaluation test in this study is as a terminal evaluation of the individual's intellectual status on the completion of the intervention strategy.

Bearing in mind guidelines suggested for the construction of evaluation tests (Herman, 1988; Hopkins and Stanley, 1981; Thorndike and Hagen, 1977; Tuckman, 1975), the first stage involved is the preparation of the test specification. This is drawn up before any items are prepared to guard against fortuitous imbalances and disproportionate item coverage (Anastasi, 1982). In this study, such specifications begin with an outline of both instructional objectives and the subject matter to be covered. In order to provide a firm basis for more precise comparison (Krathwohl and Payne 1971; De Landsheere 1988; Tuckman 1975), the evaluation test is developed in line with Bloom's taxonomy of educational objectives (Bloom, 1956). As in most tests in the classroom (Tuckman 1975), concentration is focused on the first three levels of the taxonomy; viz. knowledge, comprehension and application.

In a pure hierarchy such as Bloom's Taxonomy, achievement at a higher level is dependent upon achievement at the previous level. The hierarchical nature of the first three levels has been empirically validated (Kropp, Stoker and Bashaw, 1966; Madaus, Woods and Nuttal, 1973), but as we move towards the more complex end of

the continuum, the categorisation is compounded by the fact that the students' prior experience with the material on which the items are based may have resulted in learning by rote problems that would be complex if new to the students. As argued by Krathwohl and Payne (1971) a certain problem would drop into a lower category, such as knowledge, for the student who learned it by rote, whereas it would be a measure of more complex behaviour for the student who met it afresh.

In a similar vein, De Lansheere (1988) contends that the problem is worsened when students are presented with difficult or not well - known items, especially when the lower cognitive processes have not been sufficiently mastered to contribute significantly to the production of higher level cognitive operations. It is therefore advisable to concentrate on knowledge, comprehension and application. The definition of the three educational objectives and the corresponding example is arrayed in APPENDIX D.

Once the test specification has been established, the next concern is to specify the type of item that should be prepared. In this study, the multiple-choice form is used because it is the most popular item type and relatively straightforward to construct (Choppin 1988) with great flexibility (Thorndike and Hagen 1977). More importantly, when it is well constructed, it has the potential of assessing students' performance on a wide range of objectives involving different skill levels (Wesman 1971; Tuckman 1975).

The multiple-choice form consists of the item stem (an introductory question or incomplete statement) and two or more responses (the suggested answers to the questions or completion of the statement). The incorrect responses are the distractors (Herman 1988; Thorndike and Hagen 1977; Tuckman 1975; Wesman 1971). The distractors together with the correct answer are called the options. The typical pattern of the multiple-choice item would have four or five answer choices to reduce the probability of guessing[13] (Thorndike and Hagen 1977). The four multiple-choice

[13] $P_{RC} = P_R - P_W / k - 1$; where:

forms used in the evaluation test are the best answer variety, the multiple-choice variety and the negative variety (Wesman 1971).

The next common procedure involved in test construction is to define the level and the distribution of the difficulty of the items. To reiterate, item difficulty is commonly defined as the percentage of examinees answering the item correctly. The decision made in this regard may have major implications not only for the validity and reliability of the test, but more importantly, its general suitability for the purpose it is intended to serve (Thorndike and Hagen, 1977; Tinkelman, 1971). It is traditionally agreed that the best test is one composed of items having an optimum and narrow range of difficulty since this serves to increase not only the variance but more importantly the reliability of the test (Tinkelman, 1971).

In multiple-choice items (unlike free response type items), it is likely a certain percentage of examinees will guess at the correct answer. In other words, there exists a chance success factor in answering the items. In order to avoid greater error variance due to chance in more difficult items where more guessing will occur, a shift towards relatively easier items is strongly recommended (Choppin, 1988; Lord, 1952; Tinkelman, 1971; Torndike and Hagen, 1977). For instance, in a test composed of items with four options, the chance probability of success is .25 (1.00/4). The optimum item difficulty would be halfway between the chance probability of success and 1.00 (i.e. .63). Presumably, the remaining 27% who failed the item and guessed wrong were distributed on the average of 12% on each of the three wrong alternatives and another 12% who guessed the correct answer. Therefore, by considering the chance success factor, the optimum item difficulty for the four options multiple-choice item used in this study is .75 (.63 + .12).

Another important feature of a test plan is the specification of the number of items in the test. In a power type of test, this should be large enough to provide an

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P_{RC} : corrected proportion of correct answers
P_R : observed percent of corrected answers
P_W : observed percent of choice of wrong answers
k : number of alternatives to the item

adequate sample of students' behaviour across content and process objectives. In order to allow enough time so that 80% of the student teachers can attempt to answer every item, the evaluation test is composed of 15 items (Thorndike and Hagen, 1971) (see APPENDIX E).

Finally, an estimation of test validity was made. When dealing with a self-constructed evaluation test, one of the recommended ways of dealing with test validity is by soliciting the judgement of several independent jurists. The jurists' consensus is sought to ensure that i) each item measures what is supposed to be measured in terms of specified cognitive abilities and ii) the right items have been chosen for testing (Tuckman, 1975). The same method has been employed by Al-Qattan (1988) and recently Clauson (1997) whereby the instruments were presented to a panel of experts and the collective expert judgements were used to make the decision whether the objectives i) and ii) were accomplished.

Clauson (1997) gauged the strength of agreement among the jurists by means of *Spearman's correlation coefficients*. However, considering the small sample size involved in this study, the *Kendall's tau correlation coefficients* is preferred (Campbell, 1996; Kinnear and Gray, 1994). TABLE 4.3 presents the degree of agreement among Jurist A, Jurist B and the researcher. Analysis shows that Jurist A and Researcher are in total agreement in terms of item classification ($p=1.00$; $r<.01$). Correspondingly, both Jurist A and Researcher share the same agreement with Jurist B ($p=.54$; $r<.05$). From the magnitude of correlation coefficients, it could be inferred that the all the jurists shared the same item classification and thus underpin the researcher's a priori assumption that the evaluation test is composed of items which test for knowledge, comprehension and application in terms of educational objectives. The evaluation test used in this study is summarised in TABLE 4.4.

TABLE 4.3

KENDALL'S TAU B CORRELATION COEFFICIENTS

	Jurist A	*Jurist B*	*Researcher*
Jurist A	1.00 (p = .)	.524* (p = .028)	1.00** (p = .)

** correlation is significant at the .01 level

* correlation is significant at the .05 level

TABLE 4.4

THE CHARACTERISATION OF EVALUATION QUESTIONS

BLOOM'S TAXONOMY OF EDUCATIONAL OBJECTIVES	THE MULTIPLE-CHOICE FORMS			TOTAL
	Best Answer Variety	*Multiple Response Variety*	*Negative Variety*	
Knowledge	Q_5 , Q_7	Q_1, Q_3	Q_4	*5*
Comprehension	Q_2, Q_6, Q_{10}	Q_8	Q_9	*5*
Application	Q_{11}, Q_{12}, Q_{13}, Q_{14} & Q_{15}			*5*
Total	*10*	*3*	*2*	*15*

4.2.4. The Self-Instructional Material: A Module

A "module" is described by Russell (1974; p.2–3) as "an instructional package dealing with a single conceptual unit or subject matter". However, the module might also be integrated across a number of different subjects and be continuous, where progression can be clearly shown between different modules (Weller and Williams, 1988). Regardless as to whether it is integrated or a single subject, or continuous or discrete, each module carries in itself specific objectives, which are unequivocally stated at the outset to its clientele, even if these are very young children (Bourne, 1988; Dowdeswell, 1972; Gagné and Briggs, 1979). The quintessence of modular instruction in accomplishing objectives is stressed by Goldschmid and Goldschmid (1973; p. 23-24) in their definition of module; viz. "a self-contained, unit of a planned series of learning activities which have empirically proven effective in helping students accomplish certain well-defined objectives".

The time framework within which the learning objectives should be procured is stated in several definitions. Gagné and Briggs (1979; p.274), for instance, view the module as "a unit of study lasting approximately two weeks" which might cover 15 minutes to 15 subject hours (Dowdeswell, 1972). In terms of teaching strategies, although the work is largely self-instructional (Bangert *et al.* (1983), it is usual for it to be systematically planned and closely integrated with tutorials and supplementary reading with the use of a full range of teaching media and resources. Perhaps, this is why Bank and Ambrose (1977; p. 304) regard a module as "an outline of learning steps closely tailored to the needs of the individuals", specifying "the purpose, content, media, student grouping and the activity for each discrete step in the sequence".

A more comprehensive definition of a module is given by Warwick (1988; p. 3) who views module as "a short unit, complete in itself, which may be linked to further units towards the achievement of larger tasks or long term goals". A complete module would not only have clearly defined objectives, providing the means towards

the achievement of the ends, but built-in feedback and evaluation procedures (Bourne, 1988; Dowdeswell, 1972). Such built-in feedback is characterised by self-test and discussion questions (Gagné and Briggs, 1979) which allow for reinforcement and the formative testing for a mastery learning strategy (Russell, 1974; Bangert *et al.*, 1983). In this way learners are facilitated to achieve the specific objectives at their own rate.

4.2.4.1. Review of Studies on the Effectiveness of the Individualised System of Instruction

An early comprehensive review on the significance of the individualised system of instruction in increasing students' academic performance at the college level was pioneered by Dubin and Taveggia (1968). In this analysis, which involves over 350 research reports from 1924 to 1965, it is concluded that an individualised system of instruction is more effective than traditional college teaching methods (e.g. lecture group discussion) or media (face to face instruction). In a follow-up analysis Taveggia (1976; p. 1032) demonstrates the individualised system of instruction "has proven superior to the conventional teaching methods with which it has been compared" (Taveggia, 1976; p. 1032).

In the same year, Robin (1976) reviewed 39 studies conducted between 1969 and 1975. It was found that 77% or 30 out of 39 comparisons demonstrated significant differences in favour of the individualised system of instruction (e.g. Alba and Pennypacker, 1972; Allison, 1975; Born and Whelan, 1973; Copper and Greiner, 1971; Johnson and Pennypacker, 1971; Sheppard and MacDermot, 1970; Witters and Kent, 1972). In terms of subjects' performances, the analysis revealed that the individualised system of instruction significantly outscored the traditional instruction by average differences of 9% (I = 71%; LI: 62%). Deeper inspection of pre-post-test research designs shows that the pre-post increment averaged gains of 32% in the individualised system as opposed to 20% in the lecture recitation techniques (Robin, 1976).

Three years later, Kulik, Kulik and Cohen (1979) conducted a meta-analysis of 75 comparative studies described in 72 papers. The analysis shows that the system superiority can be demonstrated in a variety of course settings within a number of research designs. Using "effect size", analyses show that students receiving individualised instruction score on average 8% higher than those in conventional classes. The average magnitude effect size of .5 means that the individualised method of instruction could raise the final examination score of a typical student in a typical class from the 50 th percentile to the 70 th percentile.

Analyses of unpublished materials in recent years also yielded similar results. The effectiveness of the individual system of instruction in conveying content knowledge could be traced across domains of subject knowledge. Although on several occasions both techniques produced similar learning outcomes (e.g. Physical Science: Baves (1969); Biology: Grant (1982); Listening and Reading: Howell (1982); Algebra: Smith (1983)), a positive effect in favour of self-instructional is more rather than not likely to occur. Sharon (1971) shows that this system of instruction is more effective in teaching techniques of solving acid-base chemical equilibrium problems, and Ozsogomonyan (1972) shows that students' Chemistry retention skills are better when they are taught by self-instructional materials. In a Physical Geography course, the superiority of this system of instruction is demonstrated by McCall (1977) and Khan (1983) and in Mathematics by Watson (1982).

The individualised system of instruction is also widely used in teacher education programmes. Jaus (1975) demonstrates the effectiveness of individualised instruction on the learning of integrated science process skills by 90 junior-year science student teachers. Similarly Schielack (1982) showed that individualised instruction improved Mathematics achievement of 58 Mathematics student teachers at the University of Texas, the experimental group performing significantly higher in the final examination than their counterparts in the control group. A self-instructional group outperformed those in a lecture recitation group in both knowledge acquisition

and retention skills by at least 1 standard deviation in a study by Strawitz and Malone (1987). Again, Akindehin (1988) having developed an instructional package specifically designed to promote an understanding of the nature of science as part of a science teacher education programme, showed that student teachers in the experimental group acquired better understanding of the nature of science and subsequently demonstrated more favourable science-related attitudes than those who were not exposed to the instructional materials.

4.2.4.2. Advantages of Modular Instruction (MI)

Although MI is often viewed from several different perspectives, it could be synthesised that, there are a two common procedures involved and these were used as a frame of reference by the researcher in conducting this study; viz. MI begins with the pre-test and ends with the evaluation test. The main advantages of MI can be summarised as follows:

- the objectives are clearly stated in terms of students' performances and changes in attitudes. The students therefore know what is expected of them before embarking on a particular piece of work;
- learning experiences are presented in an integrated and structured manner, and the design is orientated towards the needs of the learners;
- students are enabled to break down the material into appropriate units. Not only are the learning experiences highly individualised, but so is the speed of which students move through the course;
- as a self-contained educational entity, it encourages a greater concentration on study than do more "open" situations, where large amounts of redundant information may distract certain (e.g. field dependent) learners; and
- it carries in itself a self-evaluation of mastery of the stated behavioural objectives. Thus, students are enabled to evaluate quickly their strengths and

weaknesses so that subsequent feedback in terms of remedial modules, repetition or even a change in learning mode, can be arranged.

In short, MI is successful because it encourages the achievement of objectives through a mastery of learning strategy, self-pacing and frequent feedback.

4.2.4.3. The Design of the Modularised Instructional Material (MI)

The researcher employed three phases in the writing of the MI material. The analysis phase is concerned with objectives, contexts of learners; the synthesis phase with the production of sequencing of the instructional material, and the evaluation phase with the piloting and revision of the material. The relationship between the phase is described in FIGURE 4.1.

Analysis Stage:

Prior to the construction of the module, content has to be selected. This was done by reference to the Critical and Creative Thinking Skills Syllabus Specification (Ministry of Education, 1996), a thinking skills course specifically designed for in-service teacher training in Malaysia, and the "Critical Thinking in the Laboratory" module prepared by Martin (1996). In order to produce a comprehensive coverage of the content material, extensive literature review on that topic were also used Akindehin (1988).

Subsequently, a task analysis was undertaken. In designing instructional material, task analysis refers to:

> "Several different, though interrelated procedures which are carried out to yield the system information needed to plan and specify the condition for instruction"
>
> (Gagné and Briggs, 1979; p. 114)

Specifically, a task analysis includes procedural and learning stages. The procedural stage involves the description of the steps involved in the process of performing a task or skill. The learning task analysis identifies those skills needed to perform each

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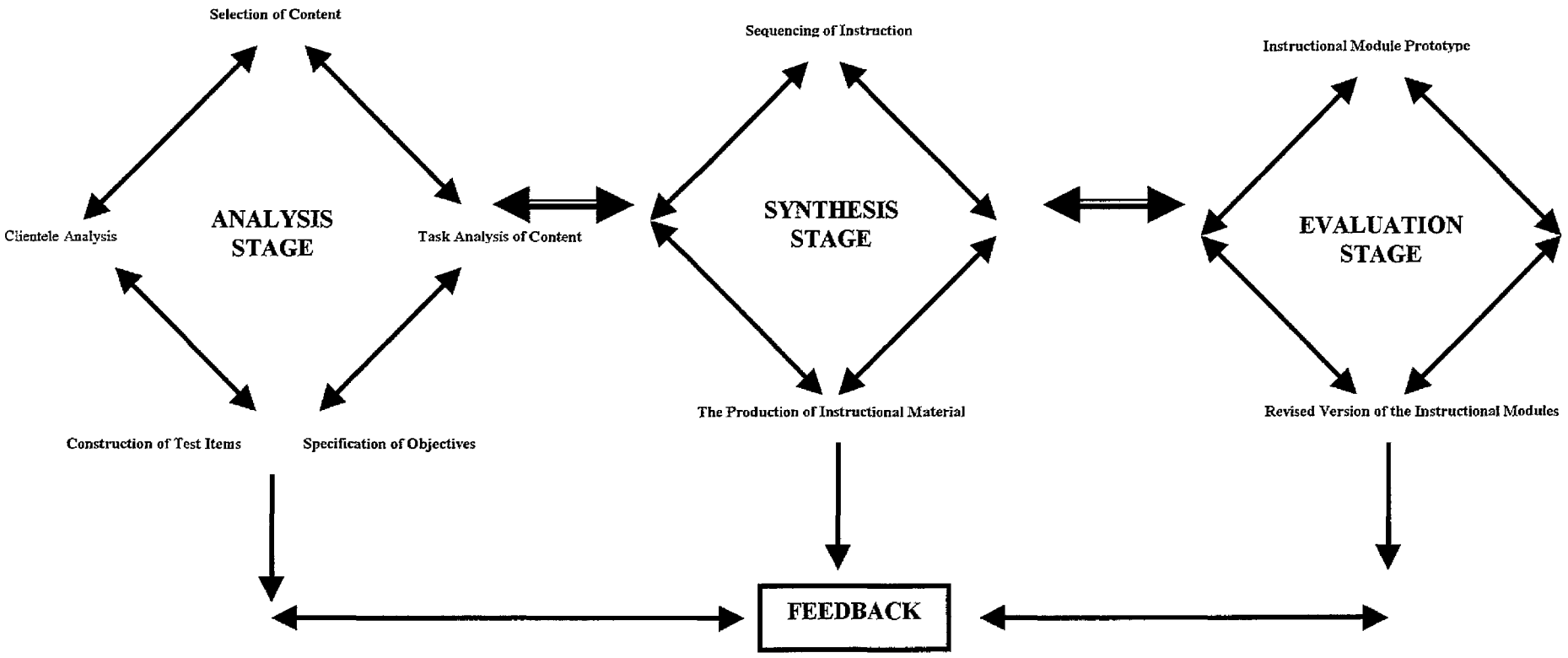
FIGURE 4.1

THE INSTRUCTIONAL DESIGN AND ITS STAGES



step in the procedural task. Task analysis plays a crucial role in specifying the module's objectives, particularly in determining any pre-requisite or prior knowledge required, and so assists in the production of the learning hierarchy that guide the sequencing of instruction.

Based on the desired terminal objectives, the instructional objectives were specified, which in turn, guided the planning and sequencing of the instructional activities, and the evaluation of intended outcomes of instruction. The production of instructional objectives was based on criteria provided by Mager (1962), Kemp (1971), Gagné and Briggs (1979), and Gagné, Briggs and Wager (1988). These are, *inter alia*,

- verbs are written in an action form to describe the action that the student must take;

  For instance: identify, describe and *underline*

- the situation under which the learners could achieve the objectives is stated;

  For instance: Using the knowledge gained from this module, identify how critical thinking is similar to, and different from, problem solving

- the performance standard that indicates the minimum acceptable accomplishment in measurable terms should be considered.

  For instance: write an essay of not more than 1000 words on....

The self-paced nature of a modularised system of instruction requires that each module be accompanied by a short-test commonly named a self-evaluation test (Gagné and Briggs, 1979; Robin, 1976; Russell, 1974;) sometimes referred to as a Unit Diagnostic - Progress test (Block and Anderson, 1975). The test result informs students of their progress and helps them improve their learning where required. The self-evaluation test is constructed in a variety of formats in order to maintain student interest and affording them the opportunity to apply the information learned in a variety of situations (Russell, 1974). Additionally, study question density or ratio of

the evaluation tests to pages must also be controlled since it must reflect the difficulty of the material (Robin, 1976).

Synthesis Stage

The synthesis stage calls for the actual construction of those elements deemed important as a result of the analysis stage. In order to meet the requirement of a theory of learning that gives high significance to the patterns in which individuals organise knowledge, the technique of "concept mapping" was applied (Novak, 1982; 1988). A concept map determines relationships between the broader principles and the concepts, and facts subsumed within these principles are made clear. FIGURE 1 (APPENDIX F) represents the concepts and relationship between concepts in the topic under consideration (i.e. critical thinking in science lessons).

Evaluation Stage

In this final stage, the module prototype was assessed by means of a pilot study. Feedback from the pilot study was taken into consideration in revising the module, particularly with regard to the suitability of learning materials to individual's needs, and the utilisation of self-motivation and reinforcement, and exercises for mastery learning. The revised module was then ready to be used as an instrument in the study (see APPENDIX G).

4.2.5. The Science Teaching Observation Schedule (STOS)

In a review of teacher-pupil interaction observation instruments, (whether designed to measure cognitive, affective, emotional climate, verbal emphasis or social organisation), Amidon and Simon (1965) are convinced that they yield data which can demonstrate generalised teaching styles (e.g. Abdullah, 1987; Buseri, 1985; Carter, 1989; Galton and Eggleston, 1979; Kassim, 1989; Muthwii, 1987). They have also been used as an indicator of pupil achievement in process-product

studies (e.g. Brophy and Goods, 1986; Needels, 1988; Wright and Nuthall, 1970) and to reveal classroom climate, perception and personality (e.g. Fish 1994; Medley and Mitzel 1958; Medley and Mitzel, 1959). Another trend is to use observational data to evaluate the teaching and learning processes directed towards specific skills; e.g. science processes (Duffy, 1996; Shymnasky and Penick, 1979; Smith, 1971; Parakh, 1967) and critical thinking skills (Kartini, 1998; Smith 1977) which themselves were ultimately geared towards the improvement of teacher education programmes (Cepni 1993; Matthews, 1967).

Since teaching and learning are bewilderingly complex phenomena, there is a high "probability of dissonance between the processes which teachers think they engage in and the realities of classroom events" (Carter, 1989; p.31). The examination of molecular classroom activities in terms of teacher and pupil behaviour provides a precise description of what actually occurs in the classroom. As Stake (1970) argues:

> "Neither an understanding of what the curriculum has been or what should be tried next time is possible without data on the teaching method. In some evaluation studies, the most valuable data will be those gathered by classroom observation"
>
> (Stake, 1970; p.5)

As in many observational research studies, this study focuses on verbal behaviours. Modern observation instrumentation reliably describes such behaviours although there may be a somewhat tenuous link between verbal behaviour as an adequate representative of total behaviour (Amidon and Hough, 1967; Flanders, 1970; Nuthall, 1970; Smith, 1977).

In essence, the instrument used in this study is designed to measure whether student teachers who have been exposed to intervention strategies (themselves aimed to encourage the students to use critical thinking), actually use critical thinking skills in the classroom. This is the final and vital step in any intervention strategy and one frequently overlooked.

The methods and concepts employed in the observational procedures conducted in this study of classrooms is discussed under three major sub-headings: i) coverage, ii) methods of data collection, and iii) unit of analysis. Considering the extensive databank available in the field, this discussion is confined to the Science Teaching Observation Schedule (STOS) used in this study.

4.2.5.1. Coverage

Like many other observational systems, the STOS is a one-factor system, which was primarily developed to measure cognitive activities involved in science teaching. Within this limitation it was considered that the STOS system provided an appropriate profile of classroom activities since the subjects of the observation are science student teachers, who at this stage of their careers cannot be expected to possess sound management skills or to have developed outstanding affective relationships with children. This is why the proponents of one-factor cognitive systems (e.g. Carter, 1989; Eggleston, Galton and Jones, 1985; Hacker, 1984; Muthwii, 1988) argue that the profile of abilities which student teachers develop and practise in the classroom are a reflection of their cognitive abilities.

STOS contains five categories. Each of these is "subscripted" into 7,4,4,4,4 minor categories and totalling altogether 23 categories (see APPENDIX H). The main dichotomies into which observations are classified are those events initiated by the teacher and those maintained by pupils. Teacher talk is further sub-divided into three major categories: teacher questions, statements and directives. Pupil activity is divided into two main categories: pupils seek information or consult, and pupils refer to the teacher. Each of these five major categories is sub-divided into minor categories, the basic pattern being interaction, which are associated with recall of facts or principles, problem solving, hypothesising and/or experimental procedures.

Although this investigation is specifically conducted to investigate the inculcation of critical thinking in science lessons, a general schedule for investigating

science lesson is used. Rosenshine (1970b) argues for the use of a general observational system and subsequent selection of the relevant sections of the instrument, which meet the specific purpose of evaluation. In a similar vein, Biddle (1967) argues that the recording of objective behaviours is more reliable, and involves fewer assumptions by the researcher, than the recording of behaviours that might attach solely to critical thinking. Additionally, STOS allows comparisons of the teaching styles employed by the Malaysian science teachers with teaching styles of student teachers from different cultural backgrounds. STOS is widely used, not merely in its country of origin (Britain), but also in Canada (Hacker, Hawkes and Hefferman, 1979), Australia (Hacker and Miles, 1980), Nigeria (Ajeyalemi, 1981), and Kenya (Muthwii, 1987).

4.2.5.2. Method of Data Collection

In this study the researcher acts as an independent, non-participating observer, who systematically observes and encodes intellectual transactions, converting behavioural events into a form suitable for counting and tabulation. The validity of the former is argued by Kerlinger (1973). Whilst having its critics, the methodology is widely used and the arguments are rehearsed only briefly here.

Several studies suggest that observed persons' behaviours are ameliorated when mediators are used as observers (Hay, Nelson and Hay, 1978; 1980; Kubany and Sloggett, 1973; Samph, 1976). This is why some researchers, in their attempt to circumvent the reactivity effect caused by non-participant observers, use participant observers. Participant observers are supposed to be less reactive to their own presence (Ball, 1988; Hay, Nelson and Hay, 1980) and in any case understand the significance of classroom events that might elude strangers (Wragg, 1994); that is, they are aware of not just what happens, but why it happens (Dunkerton, 1981). Medley and Mitzel (1963) and many others take a more balanced view, arguing that the observer's effect on teachers' behaviour, need not to be taken too seriously.

The use of systematic observation must presume that the observer presence does not substantially affect teachers' behaviours. Nevertheless, "whatever can be done to minimise the disturbing effect of the observer should be done" (Medley and Mitzel, 1963). It is suggested that the minimising of observers' effects could be achieved by keeping the observer in the observational setting long enough for him to be perceived as a "piece of furniture" (Heyns and Zander, 1953) and by locating him/her in a discreet position "where their presence will be less likely to affect events" (Wragg, 1994).

4.2.5.3. Unit of Analysis

STOS, like any other instrument which employs a sign system of observation (e.g. the OscAR technique developed by Medley and Mitzel (1958)) records the occurrences of behaviours only once, irrespective of how often it may take place in each time unit. Unlike category or rating observations, the sign system is classified as a "low inference" measure because the items focus upon specific, denotable, relatively objective behaviours. In addition to that, since the behaviours are recorded as a frequency count, it avoids the error of central tendency or "halo effect" as well as generosity or leniency errors (Medley and Mitzel, 1963; Rosenshine, 1970; Wragg, 1994).

The fixed time unit in which behaviours are recorded in STOS is commonly referred to as *One-Zero* or *unit* time sampling (Biddle, 1967; Dunkerton, 1981). Although criticised by its opponents (e.g. Dunkerton, 1981) it has been used widely due to its largely mechanical character, which facilitates objective and systematic observation. The interval 180-seconds (3 minutes) is long enough to reduce the measurement error, which has been shown by Powell *et al.* (1977) to be greater when a shorter time unit is used.

4.3. TRANSLATION OF THE STANDARDISED TESTS

In this study, the translation from English to Bahasa Melayu (Malay Language) is a central feature. The process of "decentered translation" (Waner and Campbell, 1970) was employed. Brislin (1970), Chapman and Carter (1979) and recently Yeh (1996) show that the decentered translation approach maintains the loyalty of meaning between the source and target language. Not only that, revisions to improve meanings are also permitted which would ultimately produce a concise and high degree of translation equivalency across the two versions. In order to ensure the clarity of the translated versions of the CCTDI and the CCTT, Level X, three main tasks in cross-cultural adaptation requirements developed by Guillemin, Bomvardier and Beaton (1993) were employed; viz. translation, backtranslation and review of the translation and backtranslation.

The first stage was translating the CCTDI and CCTT, Level X from English to Bahasa Melayu. A complete and accurate translation would require at least two independent translators who have a high degree of familiarity with both source and target languages (Guillemin, Bomvardier and Beaton, 1993). In order to maintain consistency, the translation of the CCTDI and CCTT, Level X was assigned to two different parties. Two Malaysians; one who holds a doctoral degree in TESL and the other with a Masters degree in the same area undertook the task of translating the CCTDI. The CCTT, Level X was translated by the researcher and another Malaysian who is bilingual in Melayu and English languages and holds a Bachelor degree in Linguistics.

In the translating back stage, the translated versions are then translated back into the original source language. This process is regarded as the most common procedure for verification and validity of the translation of an instrument for cross-cultural use (Chapman and Carter, 1979). This process also requires individuals who are bilingual in both the source and target languages (Brislin, 1970; Jones, 1987). The Bahasa Melayu translated version of the CCTDI and the CCTT, Level X were

translated back into its original form by two independent bilingual experts at the Universiti Kebangsaan Malaysia.

In maintaining cultural parity between the wording and concepts that have no equivalent meaning in Melayu language, linguistic translation (Yeh, 1996) was employed. Linguistic translation is an attempt to maintain cultural parity (Cronbach, 1990). Language is simplified to the level which permits the target audiences to grasp the task. With reference to the CCTDI, for example, item 29 "Banks should make checking accounts a lot easier to understand" (English version) was translated "Banks should make savings accounts a lot easier to understand" (Bahasa Melayu version). Thus, the maintenance of cultural parity takes precedence over literal translation. Students in Malaysia commonly have savings accounts in banks and never hold checking accounts in general. Four other minor changes were made (items 14, 20, 34 and 65).

The final stage in the translation process involved the adjudication of translation discrepancies between the translated and translated back versions into the original language. This stage involved two bilingual language experts from the Language Unit, Universiti Kebangsaan Malaysia. Both the original and translated versions of the CCTDI and CCTT, Level X was meticulously examined and adjustments, particularly in terms of Bahasa Melayu grammar, were made. Upon completion, both the CCTDI and the CCTT, Level X were presented to the samples for prior testing by means of pilot studies.

4.4. PILOT STUDY

As a small-scale model of research (Borg and Gall, 1979; McGuigan, 1990), a pilot study helps the researcher to refine the data collection plan with respect to both content and procedure to be followed. This is particularly important in establishing the reliability and validity of instruments used in cross-cultural research in order to ensure the credibility of the research findings. A comparison of the psychometric

properties of the source and target language is also made which provides additional information for assessing psychometric equivalence (Jones, 1987; Warner and Campbell, 1970). Pilot studies have been carried out when:

i) testing the reliability of the CCTT, Level X (see §4.2.1.1; page 121 - 124);

ii) testing the reliability of the CCTDI (see §4.2.2.1; page 134 - 135); and

iii) testing the suitability of the instructional module in the final stage of the construction (see §4.2.4.3; page 152)

4.5. RESEARCH HYPOTHESES

4.5.1. Student Teachers' Attitudes towards Critical Thinking

In measuring the effectiveness of the intervention strategies in altering student teachers' attitudes towards critical thinking, five main hypotheses are to be tested:

H_{o1} There is no significant difference in the measurable critical thinking attitude of the groups (test and control) before exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science instruction;

H_{o2} There is no significant difference in the measurable critical thinking attitude of the groups (test and control) after exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science instruction;

H_{o3} There is no significant difference in the measurable critical thinking attitude of male and female student teachers before/after exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science instruction;

H_{o4} There is no significant difference among the population means as far as major of specialisation is concerned; and

H_{o5} There is no significant main effect of method[14]/test time/sub-scales
There is no significant method by test time interaction effect;
There is no significant method by sub-scales interaction effect;
There is no significant test time by sub-scales interaction effect; and
There is no significant method by test time by sub-scales interaction effect.

4.5.2. Student Teachers' Critical Thinking Ability

Related to the student teachers' critical thinking ability; three main hypotheses are tested:

H_{o1} There is no significant difference in the critical thinking ability as measured by the CCTT, Level X between the experimental groups (test and control);

H_{o2} There is no significant difference between the population mean of the CCTT, Level X test score with respect to the method of the intervention strategy;

H_{o3} There is no positive, linear relationship between the critical thinking ability as measured by the CCTT, Level X and the critical thinking attitude as measured by the CCTDI.

4.5.3. Predictive Relationship between the CCTDI Pre-test and the Post-test.

In order to probe further which of the CCTDI sub-scale scores predict the CCTDI post-test scores, two hypotheses will be tested:

H_{o1} There is no significant linear relationship between the CCTDI pre-test and post-test score;

H_{o2} There is no significant linear relationship between the post-test score and best linear combination of the predictors.

[14] For instance: main effect of method means looking at the differences among methods of intervention strategy while ignoring the other independent variables (test time and sub-scales)

4.5.4. Analysis of the Evaluation Test

Student teachers' acquisition of the pedagogical content knowledge about critical thinking is measured by the evaluation test. In measuring the effectiveness of the intervention strategies in delivering pedagogical content knowledge about critical thinking, four main hypotheses are to be tested:

H_{o1} There is no significant difference in the measurable evaluation test of the experimental groups (test and control) after the exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science teaching;

H_{o2} There is no significant difference between the population mean of the evaluation score with respect to the method of intervention strategy;

H_{o3} There is no positive, linear relationship between the critical thinking attitude as measured by the CCTDI (pre-test and post-test) and score of the evaluation test (knowledge, comprehension and application) in the test and control group;

H_{o4} There is no significant main effect of method of intervention strategy/major of specialisation/evaluation score;
There is no significant method of intervention strategy by evaluation interaction effect;
There is no significant major of specialisation by evaluation score interaction effect;
There is no significant method by major of specialisation by evaluation score interaction effect.

4.6. RESEARCH DESIGN

In order to tackle the research problems a "research design" was developed. The "intact" nature of the sample under investigation (and the impossibility therefore of random assignment) justifies the use of a *quasi–experimental* research design (sometimes termed a "*compromise* design", (Kerlinger, 1973)) as being most

appropriate (Cohen and Manion, 1980; Cook and Campbell, 1979; McGuigan, 1990; Mitchell and Jolley, 1988; Robson, 1992; Tate, 1988; Tellez, 1993; Wiersma, 1969).

Campbell (1969; p. 411) stresses the importance of a "self-critical" approach to quasi-experimentation, since findings from it arguably, are never "airtight" unless an extensive effort to anticipate and minimise threats to the internal[15] and external[16] validity (Campbell and Stanley, 1963; Cook and Campbell, 1979) is made. Additionally, the design chosen must satisfy conclusion validity[17] as well as construct validity of cause and effect[18].

In order to secure construct validity in particular, a reversed-treatment design specifically known as *"the reversed – treatment non-equivalent control group design with pre-test and post-test"* (Cook and Campbell, 1979; p. 124) was employed. A diagrammatic description is given in TABLE 4.5 where X+ represents treatment given by means of self-instructional material or modular instruction and X– represents the conceptually opposite treatment that would be expected to reverse the pattern of findings in the X+ group; viz. lecture instructed group. The control group is used as a no-treatment group, in order to provide a no-cause database (Cook and Campbell, 1979) which should secure the statistical conclusion validity of the design.

4.7. PROCEDURES OF DATA COLLECTION

An initial phase of research was required to notify and acquire permission from various government agencies. Firstly permission to conduct research at the Universiti Kebangsaan Malaysia was sought and the permission letter from the

[15] Internal validity is concerned with the extent to which a study establishes whether a factor or variable has actually caused the effect that is found.

[16] External validity refers to the degree to which findings can be generalised from the specific samples in the study to some target population.

[17] Statistical conclusion validity is concerned as to whether there exists an empirical relationship between the operationalised variables in the population

[18] Construct validity determines whether the relationship between the operationalised variables could be generalised to the treatment and outcome of constructs of interest

Educational Planning and Research Division, Ministry of Education Malaysia is enclosed in APPENDIX I. Secondly, in order to enable the observation to be carried out in schools throughout the state of Selangor (the location of schools involved in the teaching practice), permission from the Selangor Department of Education also needed to be acquired (see APPENDIX J).

TABLE 4.5

THE REVERSED – TREATMENT NON-EQUIVALENT CONTROL GROUP DESIGN WITH PRE-TEST AND POST-TEST

Experimental Group	O_1	X+	O_2
	O_1	X–	O_2
Control Group	O_1		O_2

O_1 : Pre-testing
O_2 : Post-testing
X+ : a treatment that is expected to influence an effect in one direction
X– : a conceptually opposite treatment from X+
..... : Absence of random assignment

Prior to the segregation of student teachers into the experimental and control groups, they were given the CCTDI pre-test which measures their attitude towards critical thinking. This was followed by the CCTT, Level X test. It should be noted that the CCTDI is administered prior to the CCTT, Level X to decrease the likelihood of giving any cues to the respondents with respect to the responses to the items. Both the CCTDI and the CCTT, Level X were administered by following the test manuals. The intact group is then sub-divided into three groups; two experimental and one "no treatment" or control group. These were subsequently exposed to the "intervention strategy". In implementing the intervention strategy, which lasted four weeks, the

first group received treatment by self-instructional material, the second group received treatment by means of traditional lecturing method.

After the "intervention strategy", student teachers' understanding of the topic was assessed using a specifically designed evaluation test. At this point in the research design evidence should be available that informs of the critical thinking abilities and dispositions of the science student teachers prior to the intervention strategy, and the effect of the intervention strategy on critical thinking dispositions, and knowledge, understanding and ability to apply critical thinking skills. Such a classical procedure is fairly straightforward and common enough in the literature. The research design reported here, however, takes the enquiry one vital step furthers. Even if it is possible to demonstrate that one or more types of intervention strategy do lead to significant improvement in science teachers' attitudes and skills in critical thinking, this is of little worth unless the students' behaviour as teachers in science classroom changes. That is, a teacher-training programme that improves teachers' skills in critical thinking is of little value *per se* unless these teachers can use their newly acquired skills in the classroom. The experimental and control groups were therefore observed teaching science after the intervention strategy had been performed in order to obtain evidence as to whether differences in teaching behaviour could be related to the intervention strategy received. The schematic diagram of the methodological procedures implemented in this study is depicted in FIGURE 4.2.

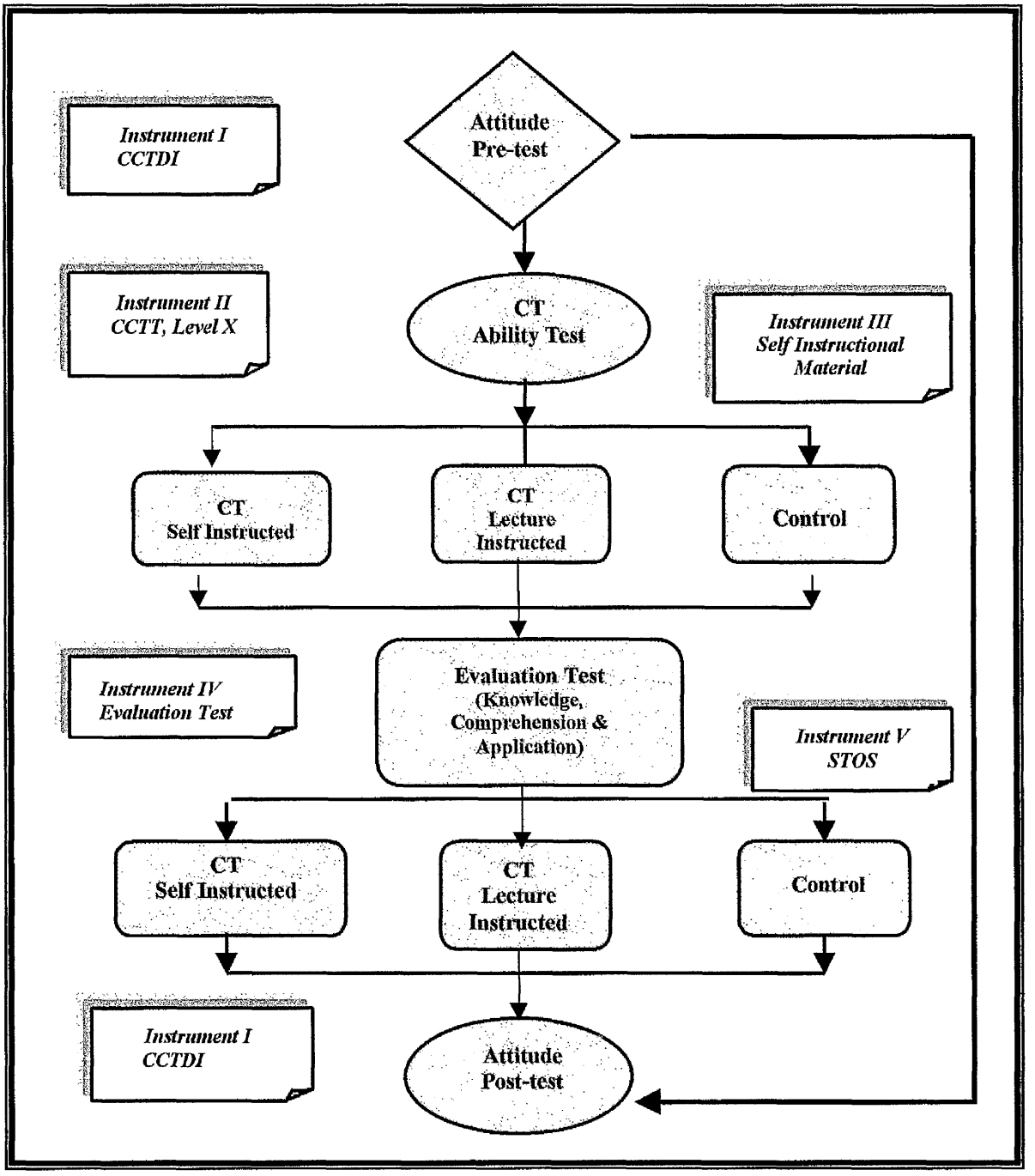
4.8. SAMPLES OF THE STUDY: THE INTACT GROUP

The intact group comprises 142 second and third year science student teachers of the Bachelor of Science (with Education) programme at the Universiti Kebangsaan Malaysia. In an attempt to reduce initial differences, and secure the internal validity of the *quasi-experiment,* student teachers were matched so that in every method of intervention strategy (self-instructed, lecture instructed and control group) there was an equal balance in terms of gender, major of specialisation as well as their previous academic achievement (viz. each group consisted of three different

achievement levels: low, average, and high). A detailed description of the intact group is presented in the next chapter (§5.2).

FIGURE 4.2

METHODOLOGICAL PROCEDURES IN DATA COLLECTION



4.9. STATISTICAL DATA ANALYSIS

In dealing with the quantifiable data gathered in this study, two main stages of statistical data analysis are employed. In the first stage, a descriptive analysis is used. Thereafter, a chain of inductive reasoning is followed. At this stage, inferential statistics are conducted in order to predict population parameters from sample measures.

The main statistical analysis used is the Multivariate Analysis of Variance (MANOVA) with repeated measures design (Huck and McLean, 1975; Howell, 1997; Jennings, 1988; Keselman *et al.*, 1980; O'Brien and Kaiser, 1985; Steven, 1992). Several other related univariate Analysis of Variance (ANOVA), student t-test, correlational and regression analyses are also be used. The main reason underlying the application of the repeated measures design is because in this design, all individual differences due to average responses of subjects are removed from the error term (individual differences are the main reason for within group variability). The *quasi-experimental* design conducted in this study is a statistically powerful design when compared with the completely randomised design in "true" experimental design (Howell, 1997; Steven, 1992). This is because the error rate per comparison[19] and the experimental error rate[20] could be reduced to the minimum (Hammel and Sligo, 1971). Multivariate Analysis of Variance is capable of showing not only the significance between total scores, but also the interaction between sub-scores. This is particularly important in this study since most of the dependent and independent variables are sub-divided into several different sub-scores and categories.

Finally, this study also employed one of the data reduction techniques. Factor analysis is used to examine the observational data because it:

---

[19] The probability that any given comparison will be declared significant when in fact the null hypothesis is true for all comparisons.

> "...enables us to see whether some underlying pattern of relationship exists such that the data may be "rearranged" or "reduced" to a smaller set of factors or components that may be taken as source variables accounting for the observed interrelations in the data"
>
> (Kim, 1975; p.469)

Successful reduction or classification of data into several major "factors" is then followed by the *Kruskal-Wallis* analysis in signifying differences, if any, across every factor with respect to the method of intervention strategy.

4.10. SUMMARY

The instrument selection is justified and psychometry of reliability and validity demonstrated via pilot studies. The writing of the modular instruction requires systematic planning and background knowledge of critical thinking and the development of appropriate skills in writing individualised learning programmes. Besides presenting the subjects with attitude inventory and evaluation test at the end of the intervention strategy, observation of behaviours is also included so that more accurate inferences could be made (Weinstein, 1989). The intervention strategy is based upon the assumption that the science student teachers, through reflective learning, will increase their professional knowledge and enhance their attitude towards critical thinking. This in turn should increase their teaching skills with respect to critical thinking. It was recognised at the outset that research design, methodological procedures, and the instruments, have some limitations. These will be discussed on the light of the results obtained in Chapters 7 and 8.

[20] This relates to experiments containing more than one comparison and there is a probability that at least one comparison will be declared significant when in fact the null hypothesis is true for all comparisons

DATA ANALYSIS AND FINDINGS (AFFECTIVE & COGNITIVE ASPECTS)

5.1. INTRODUCTION

In the quest of determining the effectiveness of teacher training in critical thinking instruction, comparison between the means by which the information is delivered always becomes the central issue. In this study, the effect of teacher training in critical thinking via self-instruction and lecture instruction is compared with the non-treatment (control) group. Specifically this chapter deals with two independent variables; student teachers' critical thinking dispositions towards critical thinking as measured by the California Critical Thinking Dispositions Inventory (CCTDI) and their mastery of the pedagogical content knowledge of how to embed critical thinking in their science instruction. In addition, data on student teachers' critical thinking ability as measured by the Cornell Critical Thinking Test, Level X (CCTT, Level X) is also presented; not merely as supplementary evidence of the homogeneity of the groups prior to the intervention strategy, but as a platform upon which the correlation between the critical thinking dispositions and critical thinking ability could be gauged.

This chapter is structured into five different segments. In the first segment, the categorical variables (gender, major of specialisation and method of intervention strategy) are used to describe the population. In the second segment, the student teachers' critical thinking attitude (pre-test) profile is depicted as the structure of the CCTDI permits (see §4.2.2) which is then followed by the depiction of the attitude towards critical thinking after the intervention strategy (post-test). This, in turn, directs the exploration of attitude change. The third segment focuses on the student teachers' critical thinking ability and its relationship with their dispositions. In the fourth segment, subsequent changes that occurred in the student teachers' critical thinking attitude form the basis of an investigation into the predictive relationship between the pre-test and the post-test scores. Finally, in the fifth segment analysis of the evaluation test is conducted in order to measure the effectiveness of the intervention strategy in terms of student teachers' mastery of the pedagogical content knowledge of how to embed critical thinking in their science instruction.

5.2. DESCRIPTIVE VALUES OF THE SAMPLES: DESCRIBING THE POPULATION

5.2.1. Gender by Major of Specialisation

TABLE 5.1

TWO-WAY FREQUENCY TABLE FOR GENDER BY MAJOR OF SPECIALISATION

(with count and all percentage)

Count *Row Pct* *Col Pct* *Tot Pct*	*MAJOR OF SPECIALISATION*				**Row Total**
	Physics	*Chemistry*	*Biology*	*Math*	
GENDER					
Female	**14** 14.7 70.0 10.7	**23** 24.2 74.2 17.6	**35** 36.8 81.4 26.7	**23** 24.2 62.2 17.6	**95** **72.5**
Male	**6** 16.7 30.0 4.6	**8** 22.2 25.8 6.1	**8** 22.2 18.6 6.1	**14** 38.9 37.8 10.7	**36** **27.5**
Column Total	**20** **15.3**	**31** **23.7**	**43** **32.8**	**37** **28.2**	**131** **100**

The relationship between gender and major of specialisation of the student teachers in the population studied is shown numerically using the two-way frequency table above. The variable categorising the group; i.e. major of specialisation forms the column of the table. Out of the 131 student teachers, more than two thirds are women teachers (72.5%). Physics is the least represented subject (15.3%), and Biology the most (32.8%). The ratio of student teachers in Physics, Chemistry, Biology and Mathematics is 1 : 1.5 : 2.2 : 1.8. In terms of gender, female student teachers demonstrate a strong propensity to specialise in Biology (36.8%), followed

by Chemistry, Mathematics and Physics. Male student teachers on the other hand prefer Mathematics (38.9%) to Chemistry, Biology and Physics. For both genders, Physics is the least attractive subject.

5.2.2. Gender by Method of Intervention Strategy

TABLE 5.2
TWO-WAY FREQUENCY TABLE FOR GENDER BY METHOD OF INTERVENTION STRATEGY
(with count and all percentage)

Count *Row Pct* *Col Pct* *Tot Pct*	*METHOD OF INTERVENTION*			**Row Total**
	CT Self-Instructed	***CT Lecture Instructed***	***Control***	
GENDER				
Female	**32** 33.7 71.1 24.4	**32** 33.7 72.7 24.4	**31** 32.6 73.8 23.7	**95** **72.5**
Male	**13** 36.1 28.9 9.9	**12** 33.3 27.3 9.2	**11** 30.6 26.2 8.4	**36** **27.5**
Column Total	**45** **34.4**	**44** **33.6**	**42** **32.1**	**131** **100.0**

CT: Critical Thinking

From the population of student teachers described in TABLE 5.1, the 131 student teachers were allocated more or less equally into three different groups: the self-instructed group, lecture instructed group, and the control group; the groups comprising 45, 44 and 42 student teachers respectively (see TABLE 5.2). Just like the overall ratio of female student teachers to male student teachers, the ratio of

female student teachers to male student teachers in each group is also 1:3. As a result, each experimental group is equally heterogeneous in terms of gender.

5.2.3. Major of Specialisation by Method of Intervention Strategy

TABLE 5.3

TWO-WAY FREQUENCY TABLE FOR MAJOR OF SPECIALISATION BY METHOD OF INTERVENTION STRATEGY

(with count and all percentage)

Count *Row Pct* *Col Pct* *Tot Pct*	*METHOD OF INTERVENTION*			**Row Total**
	CT Self-Instructed	*CT Lecture Instructed*	*Control*	
MAJOR OF SPECIALISATION				
	6	**8**	**6**	
	30.0	40.0	30.0	**20**
Physics	13.3	18.2	14.3	**15.3**
	4.6	6.1	4.6	
	11	**9**	**11**	
	35.5	29.0	35.5	**31**
Chemistry	24.4	20.5	26.2	**23.7**
	8.4	6.9	8.4	
	15	**15**	**13**	
	34.9	34.9	30.2	**43**
Biology	33.3	34.1	31.0	**32.8**
	11.5	11.5	9.9	
	13	**12**	**12**	
	35.1	32.4	32.4	**37**
Mathematics	28.9	27.3	28.6	**28.2**
	9.9	9.2	9.2	
Column Total	**45**	**44**	**42**	**131**
	34.4	**33.6**	**32.1**	**100.0**

In a similar way, the total number of student teachers is fairly distributed into each experimental group according to their major of specialisation. TABLE 5.4 summarises the heterogeneity of each group, categorised by gender and major of specialisation.

TABLE 5.4

THE CHARACTERISTICS OF THE EXPERIMENTAL GROUP DEFINED BY GENDER AND MAJOR OF SPECIALISATION

METHOD OF INTERVENTION BY GENDER	*CT Self-Instructed*		*CT Lecture Inst.*		*Control*		Row Total
	Male	*Female*	*Male*	*Female*	*Male*	*Female*	
MAJOR OF SPECIALISATION Physics	2	4	2	6	2	4	**20**
Chemistry	3	8	2	7	3	8	**31**
Biology	4	11	4	11	3	10	**43**
Mathematics	4	9	3	9	3	9	**37**
Column Total	**45**		**44**		**42**		**131**

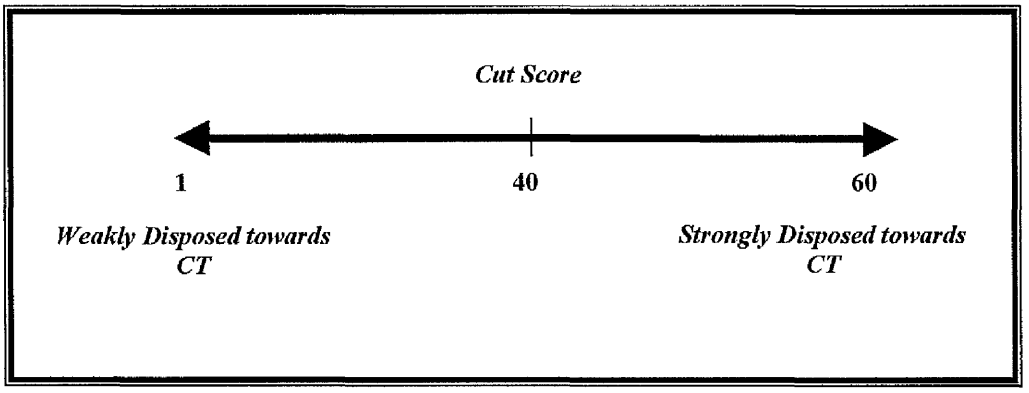
5.3. EXPLORATION OF THE CCTDI SCORE BEFORE AND AFTER THE INTERVENTION STRATEGY BY EXPERIMENTAL GROUPS

Before proceeding with the following section, it is deemed necessary to highlight the paradigm upon which the CCTDI score is based. As denoted in CHAPTER 4, the California Critical Thinking Disposition Inventory (CCTDI) comprises 75 items which could be segmented into 7 different scales; **T**ruth Seeking (12 items), **O**pen Mindedness (12 items), **A**nalyticity (10 items), **S**ystematicity (11 items), Self **C**onfidence (10 items), **I**nquisitiveness (9 items) and **M**aturity (11 items) (see also APPENDIX B and C). Thus, the CCTDI scores offer 8 scores; the seven sub-scales scores and the total scores. For each item, there is a response consonant with the disposition towards critical thinking, either " agree" or "disagree" using a six force-choice Likert scale. In this context, every student teacher is placed in a position whereby they must either agree or disagree with each item, there being no middle choice.

The response consonant with a strong disposition towards critical thinking will yield 4 or more points as opposed to responses consonant with weak disposition towards critical thinking which will yield 3 points or less. Since there is an unequal allocation of items for each sub-scale, the raw score needs to be converted into proper scale scores (range from 1 to 60) by using the "CCTDI Scale Standardisation Table" provided by the publisher (Facione and Facione, 1992). Considering the number of items for every sub-scale and points consonant with a strong/weak disposition towards critical thinking, it is recommended that the cut score for each scale is 40 and the suggested target score is 50. Student teachers who score below 40 on a given scale are conceptualised as weak in critical thinking attitudinal aspects and those who score above 50 on a scale are conceptualised as strong in that particular attitude (see FIGURE 5.1). Just as a score of less than 40 manifests weakness, an overall CCTDI total score of less than 280 shows serious overall deficiency in the disposition towards critical thinking (7 sub-scales X 40). Correspondingly, an overall

score of 350 (7 sub-scales X 50) or more is a solid indication of strength in the disposition towards critical thinking.

FIGURE 5.1
SCORE INDICATOR OF THE CCTDI



5.3.1. The CCTDI Score before the Intervention Strategy (Pre-test)

The first stage in determining the significant main effect of the intervention strategy upon the student teachers' critical thinking attitude is to compare the scores obtained by the test group (combination score of the self-instructed group and the lecture instructed group) with the control group. From TABLE 5.5, the overall mean pretest score of the CCTDI test and control groups is 261.66 and 266.40 respectively. The standard error of the mean values allows us to make a prediction of the total sample mean score of the test group and the control group (Cohen and Holliday, 1982). In the test group (n = 89), 95% of the means scores lie between 258.45 and 264.88 (261.66 ± 1.96 S.E.$_M$). The smaller number of subjects (n = 42) in the control group results in a larger standard error of the mean and the larger range value of the score. The probability of sample mean for the control group lying between 261.44 and 271.67 is 0.95. The percentages of student teachers who score below the 280 cut off points in the test and control groups are 89.9% and 76.2% respectively. From this

preliminary data it appears that this group of student teachers (test and control) demonstrates an overall deficiency in critical thinking attitude, since it falls below the 280 cut off point (refer to §5.3; page 174) and underpins the homogeneity of both test and control groups before the intervention strategy.

TABLE 5.5

SUMMARY OF THE CCTDI TEST SCORE (PRE-TEST) BEFORE THE INTERVENTION STRATEGY

CCTDI Scale	TEST GROUP				CONTROL GROUP			
	Mean	*Std. Error*	*Std. Dev*	*Mod*	*Mean*	*Std. Error*	*Std. Dev.*	*Mod*
Truth Seeking	36.09	0.40	3.80	38.00	36.83	0.68	4.44	38.00
Open Mindedness	38.52	0.37	3.49	38.00	38.98	0.63	4.08	38.00
Analyticity	39.31	0.38	3.61	39.00	40.07	0.60	3.90	41.00
Systematicity	36.80	0.37	3.52	35.00	37.95	0.50	3.25	35.00
Self Confidence	39.57	0.53	5.00	34.00	41.33	0.78	5.08	39.00*
Inquisitiveness	39.91	0.42	3.96	41.00	39.90	0.72	4.68	40.00
Maturity	31.46	0.55	5.17	32.00	31.33	0.83	5.35	27.00
Total	***261.66***	***1.62***	***15.27***	***260.00***	***266.40***	***2.61***	***16.90***	***250****

*Multiple modes exist. The smallest value is shown
Test Group: Self -Instructed + Lecture Instructed

An analysis of every sub-scale demonstrates a similar trend. Most of the student teachers possess stronger **A**nalyticity, Self **C**onfidence and **I**nquisitiveness attitudes, with in each case some 50% of student teachers scoring above the cut value of 40 points. A summary attitudinal profile is shown in FIGURE 5.2 and FIGURE

5.3. The percentage of student teachers with a score over 40 on each of the seven given disposition attributes is reported along the bottom of the horizontal axis.

Given the data from TABLE 5.5, FIGURE 5.2, AND FIGURE 5.3, it is possible to describe this group of student teachers, prior to the intervention strategy, as:

- having confidence in their own reasoning processes, being strongly and positively disposed towards inquisitiveness, and potentially users of reasoning and fact finding strategies in approaching serious problems (test group: **I** = 55.1%, **C** = 49.4%, **A** = 42.7% ; control group: **I** = 59.5%, **C** = 61.9%, **A** = 59.5%);
- possessing a moderate tolerance of divergent worldviews, although being somewhat insensitive to the possibilities of their own personal biases (test group: **O** = 33.7%; control group: **O** = 40.5%);
- being disinclined towards focus, diligence and persistence in inquiry and resisting seeking knowledge which threatens their preconceptions or interests (test group: **S** = 16.9%, **T** = 13.5%; control group: **S** = 28.6%, **T** = 28.6%) and,
- not having reached the cognitive maturity level yet (test group: **M** = 6.7%; control group: **M** = 4.8%).

Whilst therefore, both control and test groups score relatively low overall on the CCTDI attitude test, their scores on the sub-scales vary considerably and consistently. That is, for example, high scores on the Self **C**onfidence sub-scale, and low scores on the **M**aturity sub-scale.

FIGURE 5.2

CRITICAL THINKING ATTITUDINAL PROFILE OF THE STUDENT TEACHERS IN THE TEST GROUP BEFORE THE INTERVENTION STRATEGY

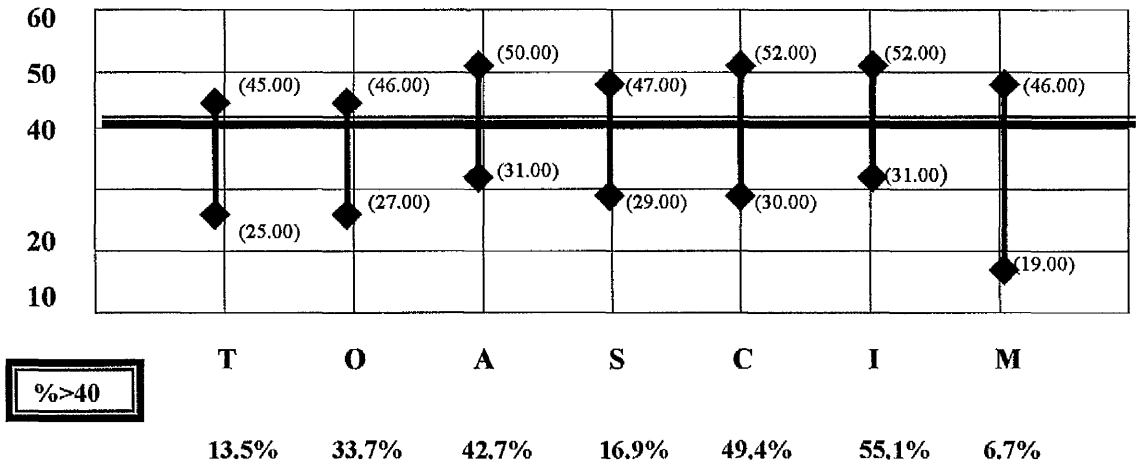
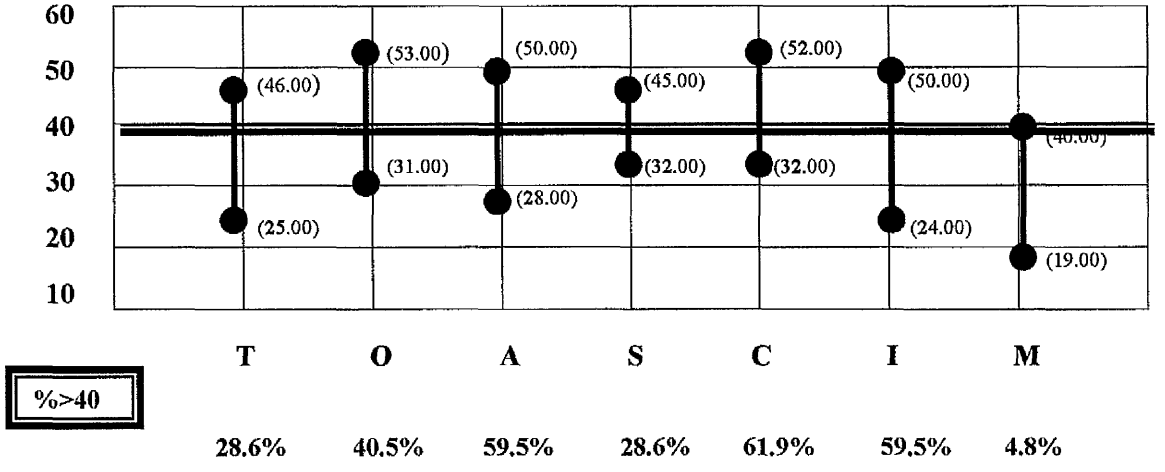


FIGURE 5.3

CRITICAL THINKING ATTITUDINAL PROFILE OF THE STUDENT TEACHERS IN THE CONTROL GROUP BEFORE THE INTERVENTION STRATEGY



5.3.2. The CCTDI Score after the Intervention Strategy (Post-test)

TABLE 5.6
SUMMARY OF THE CCTDI TEST SCORE (POST-TEST) AFTER THE INTERVENTION STRATEGY

CCTDI Scale	TEST GROUP				CONTROL GROUP			
	Mean	*Std. Error*	*Std. Dev*	*Mod*	*Mean*	*Std. Error*	*Std. Dev.*	*Mod*
Truth Seeking	38.35	0.59	5.61	38.00	36.98	0.69	4.46	34.00
Open Mindedness	40.13	0.48	4.53	43.00	39.98	0.57	3.73	38.00
Analyticity	41.10	0.40	3.82	39.00	40.83	0.62	4.03	39.00
Systematicity	40.03	0.46	4.36	38.00	38.52	0.58	3.79	35.00*
Self Confidence	43.39	0.62	5.81	43.00	42.07	0.83	5.37	40.00
Inquisitiveness	42.82	0.46	4.34	43.00	41.29	0.60	3.91	43.00
Maturity	34.38	0.67	6.28	34.00	31.36	0.73	4.71	32
Total	***280.21***	***2.39***	***22.53***	***252.00****	***271.02***	***2.49***	***16.14***	***257.00****

*Multiple modes exist
Test Group: Self -Instructed + Lecture Instructed

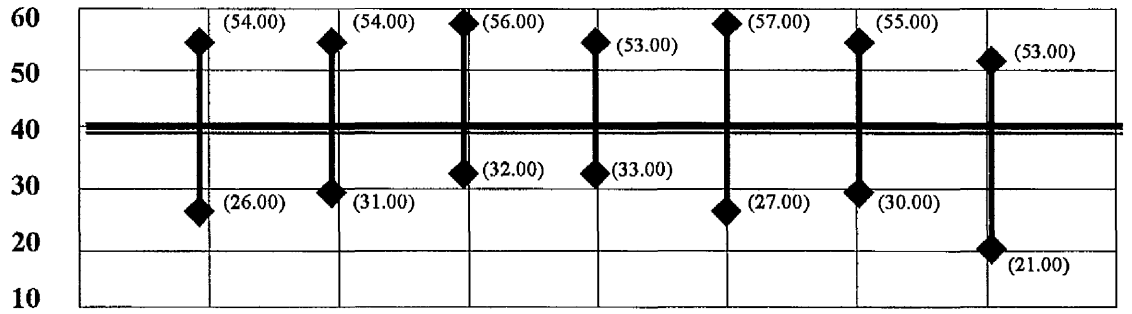
From the data in TABLE 5.6, it can be seen that there is an increase in the mean scores of both groups after the intervention strategy. For the test group, the magnitude of change is larger than the control group. The increase is 7.08% for the test group (95% of the mean post-test score for the test group lies between 275.47 and 284.96) and 1.72% for the control group (95% of the mean score lies between 265.99 and 276.05). In the test group, the percentage of those who scored less than 280 cut off points has decreased by 40.5% and 1.1% managed to gain a score of more than 350. In the control group, the percentage of those who scored below 280 only

decreased by 9.5%. Since a score of less than 280 demonstrates a weakness in critical thinking attitude, on average, the test group could be classified as just about passing this test. Even so, it could be argued that after the intervention strategy, student teachers in the test group had changed their attitude towards critical thinking. How significant is the change will be explored later.

Analysis of the sub-scales indicates an increase in terms of mean score for each of the sub-scales of the test group, some of which are quite spectacular (for example the percentage of the students above the cut point for sub-scale **S** increases from 16.9% before the intervention strategy to 50.6% after the intervention strategy). For the control group, it must be hypothesised that little change would occur, and even where there is a change, the magnitude would be low and this seems to be the case. FIGURE 5.4 and FIGURE 5.5 illustrate graphically the CCTDI attitudinal profile after the intervention strategy. Our focus will be on the test group since this is the group of student teachers that demonstrated changes in their critical thinking attitude, changes which are attributed to the intervention strategy.

FIGURE 5.4

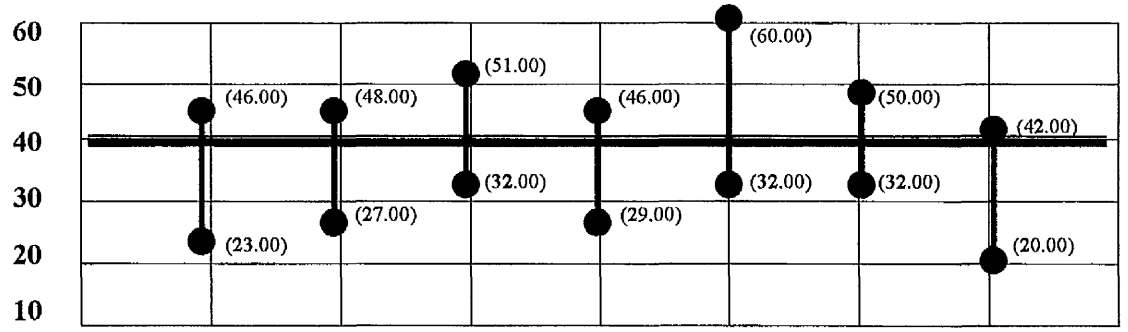
CRITICAL THINKING ATTITUDINAL PROFILE OF THE STUDENT TEACHERS IN THE TEST GROUP AFTER THE INTERVENTION STRATEGY



	T	O	A	S	C	I	M
%>40	37.1%	53.9%	62.9%	50.6%	75.3%	74.2%	22.5%

FIGURE 5.5

CRITICAL THINKING ATTITUDINAL PROFILE OF THE STUDENT TEACHERS IN THE CONTROL GROUP AFTER THE INTERVENTION STRATEGY



	T	O	A	S	C	I	M
%>40	26.2%	54.8%	61.9%	40.5%	69.0%	66.7%	4.8%

From TABLE 5.6, FIGURE 5.4, AND FIGURE 5.5, it is justifiable to conclude that after the intervention strategy, the student teachers in the test group:

- have improved their critical thinking self confidence as well as their analytical power and inquisitive traits (**C** = 75.3%, **I** = 74.2%, **A** = 62.9%);
- have improved their willingness to understand the opinion of others as well as respecting the right of others to hold different opinions (the percentage of student teachers score above 40 in the **O** scale increases 60% after the intervention strategy);
- although still having difficulties in organising themselves to approach problems systematically, they are now able to seek knowledge which threatens their preconceptions or interests (**S** = 50.6%, **T** = 37.1%); and,
- still score relatively low maturity in critical thinking attitude (**M** = 22.5%).

On the other hand, student teachers in the control group only demonstrate relatively small improvements in:

- their confidence of their own ability to reason (**C** = 69%) as well as their intellectual curiosity and learning desire (**I** = 66.7%);
- their analyticity disposition (**A** = 61.9%), but their dispositions are still influenced by their egocentric and socio-centric biases, of which they are seldom aware (the percentage of student teachers scoring above 40 in the **O** scale only increases to 35.3% after the intervention strategy); and
- their problem solving and decision making approaches (**S** = 40.5%); but
- their truth-seeking attitude decreases (the percentage of student teachers scoring above 40 in the **T** scale decreases by 8.39%).

TABLE 5.7

QUALITTATIVE AND QUANTITATIVE CHANGES BEFORE AND AFTER THE INTERVENTION STRATEGY DEMONSTRATED BY THE TEST GROUP

CCTDI Scales	PRE-TEST		POST-TEST		% DIFFERENCE	
	Mean	% > 40	Mean	% > 40	Mean	% > 40
Truth Seeking	36.09	13.5	38.35	37.1	+6.26	+174.81
Open Mindedness	38.52	33.7	40.13	53.9	+4.18	+59.94
Analyticity	39.31	42.7	41.10	62.9	+4.55	+47.31
Systematicity	36.80	16.9	40.03	50.6	+8.78	+199.41
Self Confidence	39.57	49.4	43.39	75.3	+9.65	+52.43
Inquisitiveness	39.91	55.1	42.82	74.2	+7.29	+34.66
Maturity	31.46	6.7	34.38	22.5	+9.28	+235.82

TABLE 5.8

QUALITTATIVE AND QUANTITATIVE CHANGES BEFORE AND AFTER THE INTERVENTION STRATEGY DEMONSTRATED BY THE CONTROL GROUP

CCTDI Scales	PRE-TEST		POST-TEST		% DIFFERENCE	
	Mean	% > 40	Mean	% > 40	Mean	% > 40
Truth Seeking	36.83	28.6	36.98	26.2	+0.41	-8.39
Open Mindedness	38.98	40.5	39.98	54.8	+2.57	+35.31
Analyticity	40.07	59.5	40.83	61.9	+1.90	+4.03
Systematicity	37.95	28.6	38.52	40.5	+1.50	+41.60
Self Confidence	41.33	61.9	42.07	69.0	+1.79	+11.47
Inquisitiveness	39.90	59.5	41.29	66.7	+3.48	+12.10
Maturity	31.33	4.8	31.16	4.8	-0.54	+0.00

FIGURE 5.6

INCREASING PATTERN OF THE CCTDI SUB-SCALES SCORES BEFORE AND AFTER THE INTERVENTION STRATEGY IN THE TEST GROUP

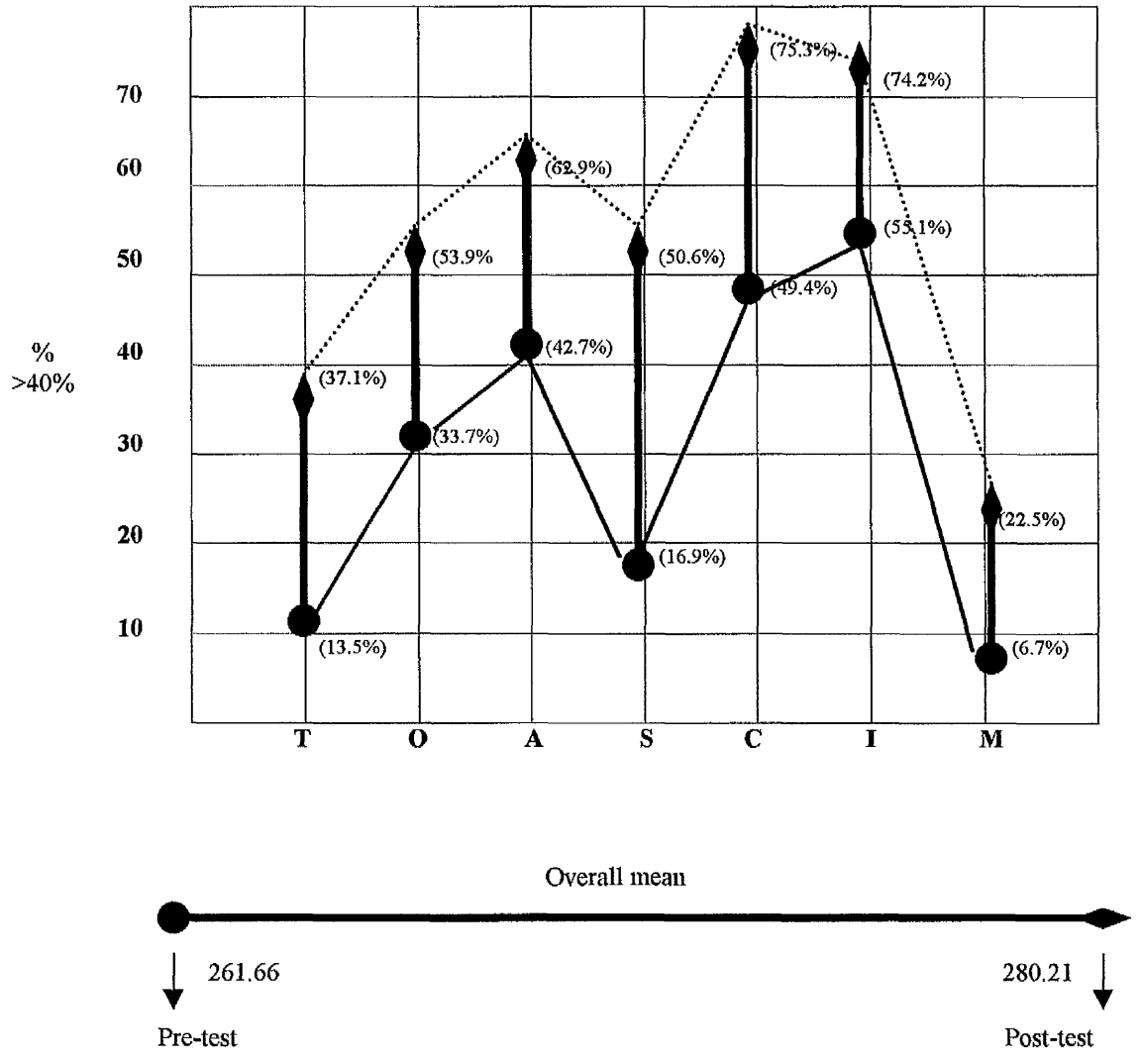
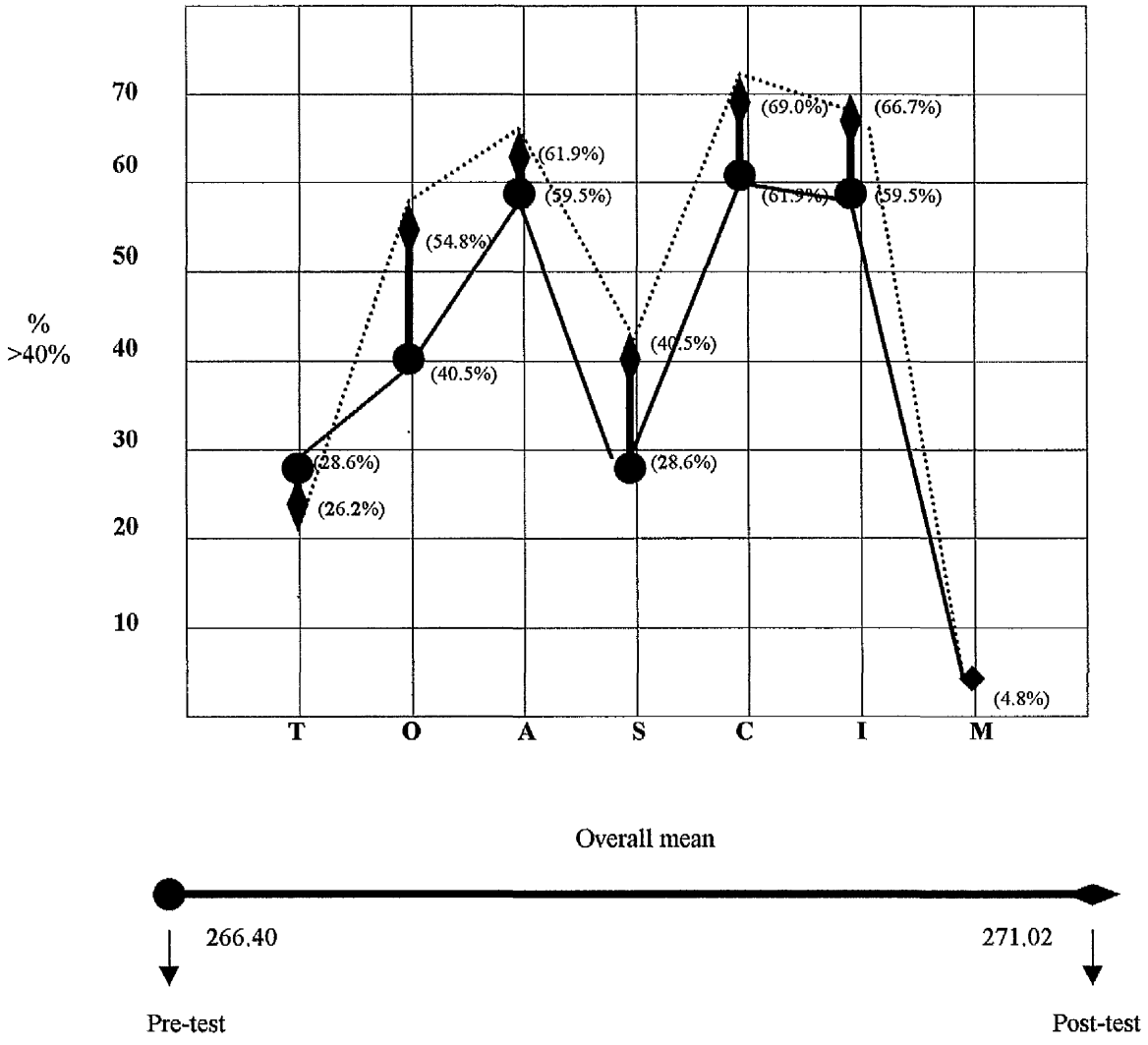


FIGURE 5.7

INCREASING PATTERN OF THE CCTDI SUB-SCALES SCORES BEFORE AND AFTER THE INTERVENTION STRATEGY IN THE CONTROL GROUP



5.3.3. Summary of the Descriptive/Explorative Findings of the CCTDI

This section considers the descriptive changes that occurred between the pre- and post-test scores for the test group. The numerical value of changes summarised in TABLE 5.7 and TABLE 5.8 is enhanced by FIGURE 5.6 and FIGURE 5.7, which visually represents the trend of change of every sub-scale in the test and control group before and after the intervention strategy. From TABLE 5.7 and FIGURE 5.6, it appears that the intervention strategy correlates with a large positive effect on the **M**aturity (+235.8%), **S**ystematicity (+199.41%) and **T**ruth Seeking (+174.8%) scales. The increasing value of the mean difference score, which symbolises the magnitude of change, is followed with the numbers of those who score above 40 (quality). Whilst a medium effect is shown on the **O**pen Mindedness (+59.94%), Self **C**onfidence (+52.43%) and **A**nalyticity (+47.31%) sub-scales, the effect on the **I**nquisitiveness (+34.66) sub-scale is the weakest. In the control group, the student teachers only managed to improve their **S**ystematicity (+41.60%) and **O**pen Mindedness (+35.10%) attitudes. Their **M**aturity remains unchanged, and their **I**nquisitiveness (+12.10%), Self **C**onfidence (+11.47%) and **A**nalyticity (+4.03) traits show relatively small changes.

The broken lines and the direction of arrows in FIGURE 5.6 and FIGURE 5.7 demonstrate the same pattern of scoring in both the pre-test and the post-test. It appears that there exists an ordinal interaction between the pre- and the post-test scores in both groups. In the control group, the "ceiling effect" is reflected by relatively small changes in the **I**nquisitiveness, Self **C**onfidence and **A**nalyticity scales (FIGURE 5.7). Since both groups were receiving different treatments, the magnitude of the "ceiling effect" is different from one group to another. By comparing the distance between the adjoining pre-test and post-test lines in both groups, it can be argued that the effect is relatively larger in the test group than in the control group. It might be possible to argue a "ceiling effect" on the smaller gains made on those sub-scales with a relatively high pre-test scores (e.g. **I**nquisitiveness in the test group) as compared with the higher increases in **S**ystematicity, which started

from a lower pre-test score (see FIGURE 5.6). In any case, one would not expect significant changes on the **M**aturity sub-scale since only a three month period elapsed between the pre and the post-test.

5.3.4. Inferential Statistics on the CCTDI

The following section examines the statistical significance of the changes discussed descriptively in the preceding sections. From a consideration of the categorical variables (independent variables) representing the samples (method of intervention strategy, gender and major of specialisation) (see also §5.2), five main hypotheses are presented.

5.3.4.1. Hypothesis One

The distribution of the interval variables involved in this study was proven as normal in character by applying the widely used rule of thumb suggested by Moore and McCabe (1993)[21]. The fulfilment of the normality requirements allows an independent sample t-test, together with Levene's test of equality of variance to be performed (Cohen and Holliday, 1982; Norusis, 1991). Such a test is vital in determining whether both the test and control groups are likely to be drawn from the same population. Since the actual behaviour of the data is not known, it is necessary to allow for all eventualities, and the two-tailed test is applied (Bryman and Carter, 1990; Campbell, 1996; Howell, 1997). The empirical agenda started with the testing of the following null (H_o) and alternative (H_1) hypotheses:

H_{01} There is no significant difference in the measurable critical thinking attitude of the groups (test and control) before exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science teaching; and

[21] $-0.5 \leq$ sample skewness $\leq +0.5$ and $-1.0 \leq$ sample kurtosis $\leq +1.0$

H_{11} There is a significant difference in the measurable critical thinking attitude of the groups (test and control) before exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science teaching

TABLE 5.9 summarises the output of the independent sample t-test. From TABLE 5.9, the mean difference between the experimental groups is 4.74 and the score of control group (mean score: 266.40) is close to that of the test group (mean score: 261.66). The sample standard deviations are also quite similar (15.27 and 16.90), Levene's test accepts the null hypothesis that the two groups have the same population variance ($p = .552$) at the 5% significance level. The second part of the output displays the result of the t-test. Levene's test suggests that the above line is relevant. The value of the t-statistic is -1.602, and its two-tailed p-value is .112, indicating a value of more than 0.05. Therefore the underlying null hypothesis (H_{01}) is accepted and it can be concluded that the two groups have been shown to have been selected from the same population.

TABLE 5.9

STUDENT'S T-TEST COMPARING MEANS OF PRE-TEST SCORE BY EXPERIMENTAL GROUPS

Variable	Number of cases	Mean	Standard Deviation	SE of Mean
PRE-TEST SCORE				
Test Group	89	261.66	15.27	1.62
Control Group	42	266.40	16.90	2.61

Levene's Test for Equality of Variances F = .355 P = .552

T-TEST FOR EQUALITY OF MEANS

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	*-1.602*	*129*	*.112*	*2.96*	*(-10.6, 1.11)*
Unequal	-1.545	73.609	.127	3.07	(-10.86, 1.37)

5.3.4.2. Hypothesis Two

After the intervention strategy, we need to know whether there is a significant difference of the mean post-test score between the groups. Since only the test group has received the exposure of the teaching of critical thinking in science classrooms (the intervention strategy), we might expect that this group would perform significantly higher in the post CCTDI than the control group. Such a prior expectation means that we are looking at the direction in which an expected difference between the test and control group might lie, which suggests the application of a directive, one-sided test (Campbell, 1996). To test whether the test group score is significantly higher than the control group, we would use the same null and alternative hypotheses as before:

H_{02} There is no significant difference in the measurable critical thinking attitude of the groups (test and control) after exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science teaching; and

H_{12} The test group has a significant higher post-test mean than the control group after exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science teaching

TABLE 5.10 shows that the mean score for the test group is 3.3% higher from the control group. The standard deviations of the test and control group are 22.53 and 16.14 respectively. Levene's test of equality of variance suggests the inequality of variance between the groups. By referring to the bottom line of the t-test output table, the t-value is 2.370 and its one-tailed p-value is 0.0095 (.019 divided by 2), indicating a value of less than 0.005. Therefore the null hypothesis that the two groups have the same population means is rejected in favour of the alternative hypothesis that the test group scored significantly higher than the control group.

TABLE 5.10

STUDENT'S T-TEST COMPARING MEANS OF POST-TEST SCORE BY EXPERIMENTAL GROUPS

Variable	Number of cases	Mean	Standard Deviation	SE of Mean
POST-TEST SCORE				
Test Group	89	280.21	22.53	2.39
Control Group	42	271.02	16.14	2.49

Levene's Test for Equality of Variances F = 4.293 P = .040

T-TEST FOR EQUALITY OF MEANS

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	2.370	129	.019	3.88	(1.52, 16.86)
Unequal	*2.664*	*108.374*	*.009**	*3.45*	*(2.35, 16.03)*

* significant at $\alpha = 0.05$

The output of the independent sample t-test highlighted in TABLE 5.9 and TABLE 5.10 bring us to the conclusion that although both groups were selected from the same population, there exists a significant difference in the post-test mean between the groups. In order to further examine the effect of the intervention strategy upon the CCTDI scores of these experimental groups, the mean difference of both groups before and after the intervention strategy were measured and significant differences between the pre-test and post-test score were determined by using t-test for correlated data (paired samples t-test). TABLE 5.11and TABLE 5.12 summarise the output of the paired samples t-tests for test group and control groups respectively.

From TABLE 5.11, although the magnitude of the t value for correlated means of every sub-scale ranges from 3.10 to 7.59, the overall t-value for the test group is quite high (9.456). Each sub-scale also demonstrates a significant increase in mean score after the intervention strategy ($p < 0.05$). We conclude that for the test group, the mean post-test scores are higher than the mean pre-test scores for each sub-scale. The output summarised in TABLE 5.12 shows that although the overall mean score gives a significant result; viz. there is a significant difference between the mean post-test and the pre-test score, the mean differences at sub-scale levels indicate only one significant result, Inquisitiveness ($t=2.09$; $p < 0.05$).

TABLE 5.11

PAIRED SAMPLES T-TEST COMPARING MEAN OF CCTDI SCORE OF THE TEST GROUP

Post-test – Pre-test (sub-scale)	Mean	Std Dev.	Std. Error Mean	95% CI for Diff.	t	Sig. (2-tailed)
Truth Seeking	2.26	5.65	.60	(1.07, 3.45)	3.770	.000*
Open Mindedness	1.62	4.92	.52	(.58, 2.65)	3.102	.003*
Analyticity	1.79	4.25	.45	(.89, 2.68)	3.964	.000*
Systematicity	3.24	4.02	.43	(2.39, 4.08)	7.589	.000*
Self Confidemce	3.82	6.11	.65	(2.53, 5.11)	5.889	.000*
Inquisitiveness	2.91	4.57	.48	(1.95, 3.87)	6.005	.000*
Maturity	2.92	6.63	.70	(1.52, 4.32)	4.155	.000*
Total	**18.55**	**18.51**	**1.96**	**(14.65,22.45)**	**9.456**	**.000***

N = 89; df = N-1

*significant at α =0.005

TABLE 5.12

PAIRED SAMPLES T-TEST COMPARING MEAN OF CCTDI SCORE OF THE CONTROL GROUP

Post-test – Pre-test (sub-scale)	Mean	Std Dev.	Std. Error Mean	95% CI for Diff.	t	Sig. (2-tailed)
Truth Seeking	.14	5.74	.89	(-1.65, 1.93)	.161	.872
Open Mindedness	1.00	3.68	.57	(-.15, 2.15)	1.763	.084
Analyticity	.76	4.11	.63	(-.52, 2.04)	1.202	.236
Systematicity	.57	3.57	.55	(-.54, 1.68)	1.038	.306
Self Confidemce	.74	5.69	.88	(-1.03, 2.51)	.841	.405
Inquisitiveness	1.38	4.27	.66	(, 2.71)	2.095	.042*
Maturity	0.03	5.76	.89	(-1.77, 1.82)	.027	.976
Total	**4.62**	**7.96**	**1.23**	**(2.14, 7.10)**	**3.761**	**.010***

N = 42; df = N – 1
* significant at $\alpha = 0.05$

5.3.4.3. Hypothesis Three

The discussion so far has focussed on the mean differences between the post-test and pre-test scores for the test and control groups. However, as indicated earlier, samples involved in this study are not only categorised in terms of experimental groups (test and control), but also in terms of gender and major of specialisation. The following sections examine the relationship between student teachers' achievement in the CCTDI test with gender and major of specialisation. In exploring a relationship between the CCTDI pre-test/post-test score and gender, the following hypotheses will be tested:

H_{03} There is no significant difference in the measurable critical thinking attitude of male and female student teachers before/after exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science teaching; and

H_{13} There is a significant difference in the measurable critical thinking attitude of male and female student teachers before/after exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science teaching

An independent t-test was performed between male and female and the output is summarised in TABLE 5.13. Levene's test of equality of variance gave an insignificant result and the null hypothesis that there is no significant difference of the population variance is accepted. The value of the t-statistic is -.988 and its two-tailed p-value is .325, indicating a value of more than .005. Therefore, the null hypothesis that both male and female student teachers have the same population mean score of CCTDI pre-test is accepted.

Analysis of the post-test score produced the same result (see TABLE 5.14). Male student teachers only managed to score 1.476% higher than their female counterparts. Results indicate that even if there exists a significant difference in the overall mean pre-test and post-test score for both experimental groups, such a difference is not correlated with gender.

TABLE 5.13

STUDENT'S T-TEST COMPARING MEANS OF PRE-TEST SCORE BY GENDER

Variable	Number of cases	Mean	Standard Deviation	SE of Mean
PRE-TEST SCORE				
Female	95	262.43	15.90	1.63
Male	36	265.17	15.95	2.66

Levene's Test for Equality of Variances F = .004 P = .948

T-TEST FOR EQUALITY OF MEANS

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	*-.878*	*129*	*.382*	*3.11*	*(-8.90, 3.43)*
Unequal	-.877	63.014	.384	3.12	(-8.97, 3.50)

TABLE 5.14

STUDENT'S T-TEST COMPARING MEANS OF POST-TEST SCORE BY GENDER

Variable	Number of cases	Mean	Standard Deviation	SE of Mean
PRE-TEST SCORE				
Female	95	276.15	21.63	2.22
Male	36	280.22	19.53	3.26

Levene's Test for Equality of Variances F = .232 P = .631

T-TEST FOR EQUALITY OF MEANS

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	*-.988*	*129*	*.325*	*4.13*	*(-12.24 4.09)*
Unequal	-1.034	69.484	.305	3.94	(-11.93,3.78)

5.3.4.4. Hypothesis Four

The effect of major of specialisation upon student teachers' performance on the pre-test and post-test score is examined using a One Way Analysis of Variance (ANOVA). The three basic precursors of ANOVA have been satisfied: homogeneity of variance, normality and independence of observations. Unequal sample size among the groups (Physics (20), Chemistry (31), Biology (37), and Mathematics (39)) is coped with by applying the *harmonic mean sample size* (30.179) (Cohen, 1977; Howell, 1977). The hypotheses to be tested are:

H_{04} There is no significant difference among the population means as far as major of specialisation is concerned; and

$$\mu_{Physics} = \mu_{Chemistry} = \mu_{Biology} = \mu_{Mathematics}$$

H_{14} That there is some significant difference between the population mean (i.e. they are not all the same)

$$\mu_{Physics} \neq \mu_{Chemistry} \neq \mu_{Biology} \neq \mu_{Mathematics}$$

The summary table of analysis of variance which compares means of the pre-test score is shown as TABLE 5.15. From the table, the difference between the highest mean score and the lowest mean score of the student teachers identified by their major of specialisation is only 2.66 units. This is a result of a small value of treatment effect ($SS_{Between}$) relative to the value of error effect (SS_{Within}). Small value of treatment effect means a lower value of an estimation of population variance due to major of specialisation difference ($M_{Between}$). Since (M_{Within}) is an estimation of population variance, the degree to which (M_{Within}) is influenced by ($M_{Between}$) is a key indicator of the significance power of the major of specialisation in characterising the mean of the pre-test score. The F value of .228 is not significant at 5% level of significance and the null hypothesis that the student teachers have the same pre-test mean and variance regardless of their major of specialisation is accepted.

A similar output was demonstrated after the intervention strategy (TABLE 5.16). Although the range between the highest and the lowest score increases by 67.7%, a lower F value also indicates insignificant results ($p>.05$). It can be concluded that student teachers' expertise in their discipline area could not be conceptualised as a factor in determining their attitude towards critical thinking. These insignificant results rationalise our reason of not operating the relevant *post hoc* test or making any further reference to gender and major of specialisation.

TABLE 5.15

ONE-WAY ANALYSIS OF VARIANCE COMPARING MEANS OF PRE-TEST SCORE BY MAJOR OF SPECIALISATION

MAJOR OF SPECIALISATION	Mean	Std Error	Std Deviation
Physics (20)	261.95	3.79	16.93
Chemistry (31)	264.61	2.69	14.96
Biology (43)	262.02	2.44	16.01
Mathematics (37)	264.00	2.78	16.47
Total (131)	263.18	1.39	15.90

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	3	176.321	58.774	.228	.877
Within Groups	127	32697.282	257.459		
Total	130	32873.603			

TABLE 5.16

ONE-WAY ANALYSIS OF VARIANCE COMPARING MEANS OF POST-TEST SCORE BY MAJOR OF SPECIALISATION

MAJOR OF SPECIALISATION	Mean	Std Error	Std Deviation
Physics (20)	279.55	5.75	25.70
Chemistry (31)	278.16	3.58	19.95
Biology (43)	275.09	2.71	17.79
Mathematics (37)	277.81	3.84	23.34
Total (131)	277.27	1.84	21.08

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	3	343.202	114.401	.253	.859
Within Groups	127	57406.447	452.019		
Total	130	57749.649			

5.3.4.5. Hypothesis Five

TABLE 5.17

THE STRATIFICATION OF THE CCTDI SCORE BY METHOD OF INTERVENTION STRATEGY

THE CCTDI SUB-SCALES	METHOD OF INTERVENTION STRATEGY											
	Self-Instructed				*Lecture Instructed*				*Control*			
	Pre-test		*Post-test*		*Pre-test*		*Post-test*		*Pre-test*		*Post-test*	
	Mean	*Std Dev*	*Mean*	*Std Dev*	*Mean*	*Std Dev*	*Mean*	*Std Dev*	*Mean*	*Std Dev*	*Mean*	*Std Dev*
Truth Seeking	36.56	3.63	40.44	5.94	35.61	3.95	36.20	4.36	36.83	4.44	36.98	4.46
Open Mindedness	38.51	3.60	41.36	4.78	38.52	3.42	38.89	3.92	38.98	4.08	38.98	3.73
Analyticity	38.91	3.74	41.76	4.29	39.73	3.47	40.43	3.18	40.07	3.90	40.83	4.03
Systematicity	36.98	4.03	41.53	4.54	36.61	2.95	38.50	3.62	37.95	3.25	38.52	3.79
Self Confidence	39.40	5.08	43.69	6.22	39.75	4.97	43.09	5.40	41.33	5.08	42.07	5.37
Inquisitiveness	39.98	4.53	43.71	4.87	39.84	3.33	41.91	3.54	39.90	4.68	41.29	3.91
Maturity	31.36	4.62	36.38	6.03	31.57	5.72	32.41	5.96	31.33	5.35	31.36	4.71
Total	261.7	16.69	288.8	25.38	261.6	13.87	271.4	14.95	266.4	16.90	271.0	16.14

$N_{Self\text{-}Instructed}$= 45; $N_{Lecture\ Instructed}$= 44; $N_{Control}$= 42

Empirical data in the previous section has provided evidence that student teachers in the test group have demonstrated significant changes in their CCTDI post-test score. As indicated earlier, there are two different methods by which student teachers in the test groups were treated; self-instructed and lecture instructed. In this section, analysis of main effect of method, test time (pre-test and post-test), CCTDI sub-scales and the interactions among the three factors are conducted. The numerical values involved in the design is summarised in TABLE 5.17 and the analysis involved is Multivariate Analysis of Variance (MANOVA) with repeated measures design with one between subjects variable (method of intervention strategy) and two

within subjects variables (test time and sub-scales). The null hypotheses to be tested in this 3 X 2 X 7 design are as follows:

H_{05} There is no significant main effect of method/ test time/sub-scales;
There is no significant method by test time interaction effect;
There is no significant method by sub-scales interaction effect;
There is no significant test time by sub-scales interaction effect; and
There is no significant method by test time by sub-scales interaction effect

It was found that both multivariate and univariate analysis of variance presented the same main effect on every factor at the 0.05 level of significance. As suggested by Steven (1992), since both Greenhouse-Geisser Epsilons are more than 70 (See TABLE 5.18) preference should be given to univariate analysis. Additionally the univariate test is more powerful since type I error (α) is controlled[22] (Howell, 1997).

A summary of results is presented in TABLE 5.18. The main effect of method is significant at the 0.05 level of significance ($F=3.45$, $p<.05$); the test time main effect ($F = 123.13$, $p<.05$) and test time by method (first order) interaction ($F = 29.97$, $p<.05$) are also significant at the 0.05 level of significance. The main effect of sub-scales is also significant ($F = 103.54$, $p < .05$) at the 0.05 level of significance. FIGURE 5.8 and FIGURE 5.9 plot the interaction between method and test time and test time and sub-scales respectively.

[22] Power of a test is a function of α (the probability of Type I error), H_1 (the difference between μ_0 and μ_1), N (number of samples) and σ^2 (variance).

TABLE 5.18

UNIVARIATE ANALYSIS OF VARIANCE FOR ONE BETWEEN SUBJECT (METHOD OF INTERVENTION STRATEGY) AND TWO WITHIN SUBJECTS (TEST TIME AND SUB-SCALES)

UNIVARIATE TESTS OF HYPOTHESES FOR WITHIN SUBJCETS EFFECTS

SOURCE	DF	SUM OF SQUARE	MEAN SQUARE	F VALUE	SIG. OF F
TEST TIME	1	1791.33	1791.33	123.13	.000*
TEST TIME X METHOD	2	872.04	436.02	29.97	.000*
ERROR (TEST TIME)	128	1862.25	14.55		

SOURCE	DF	SUM OF SQUARE	MEAN SQUARE	F VALUE	SIG. OF F
SUB-SCALES	6	10861.09	1810.18	103.54	.000*
SUB-SCALES X METHOD	12	309.62	25.80	1.48	.128
ERROR(SUB-SCALES)	768	13427.19	17.48		

GREENHOUSE – GEISSER EPSILON = .67822
HUYNH – FELDT EPSILON = .71421

SOURCE	DF	SUM OF SQUARE	MEAN SQUARE	F VALUE	SIG. OF F
TEST TIME X SUB-SCALES	6	4787.07	797.84	55.95	.000*
METHOD X TEST TIME X SUB-SCALES	12	200.33	16.69	1.17	.300
ERROR (TEST TIME X SUB-SCALES)	768	10951.62	14.26		

GREENHOUSE – GEISSER EPSILON = .75881
HUYNH – FELDT EPSILON = .80254

TEST OF HYPOTHESES FOR BETWEEN SUBJECTS EFFECTS

SOURCE	DF	SUM OF SQUARE	MEAN SQUARE	F VALUE	SIG. OF F
METHOD	2	522.58	261.29	3.45	.035*
ERROR(METHOD)	128	9689.31	75.70		

*significant at $\alpha = .05$

FIGURE 5.8

TEST TIME BY METHOD OF INTERVENTION STRATEGY INTERACTION

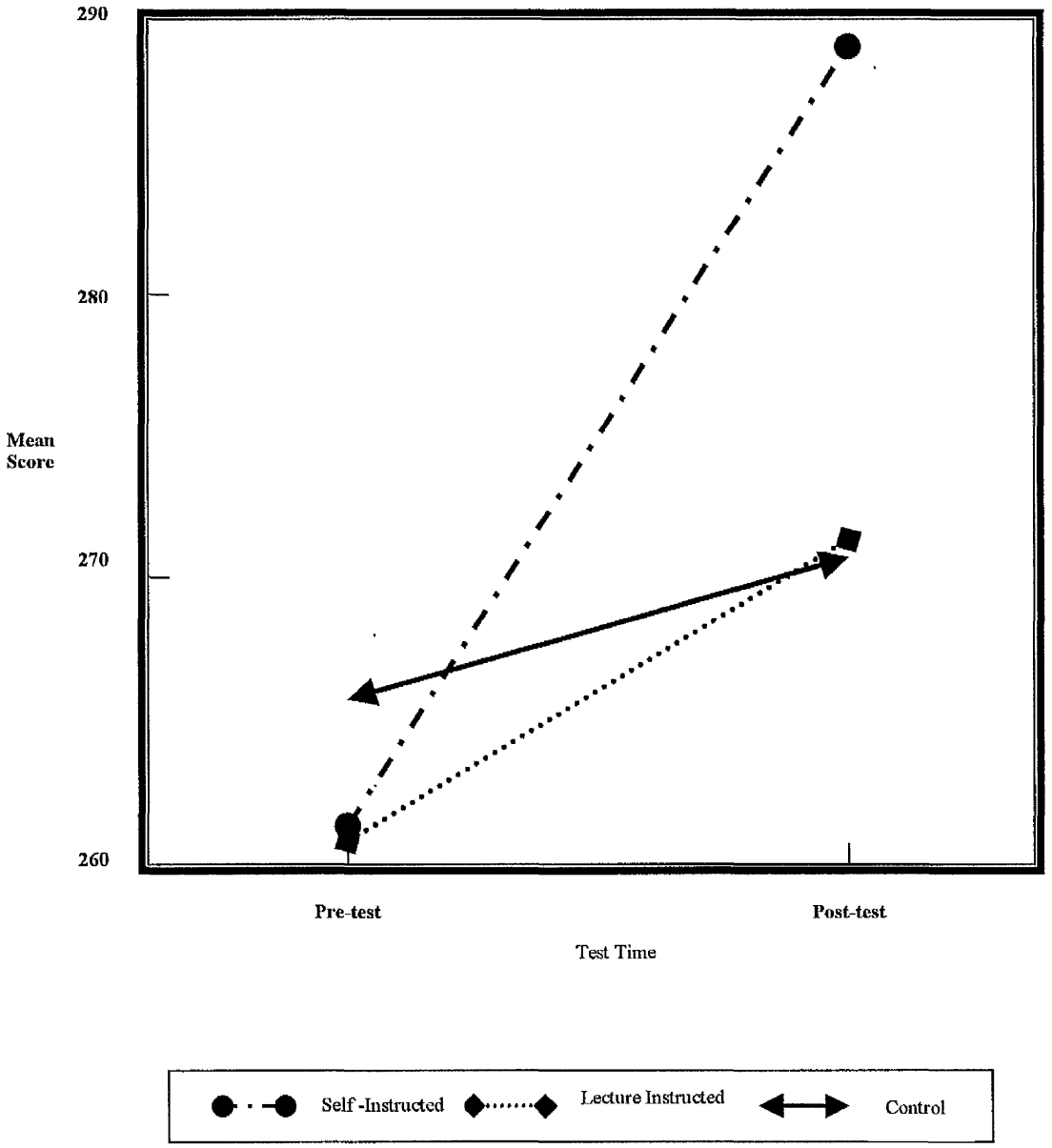
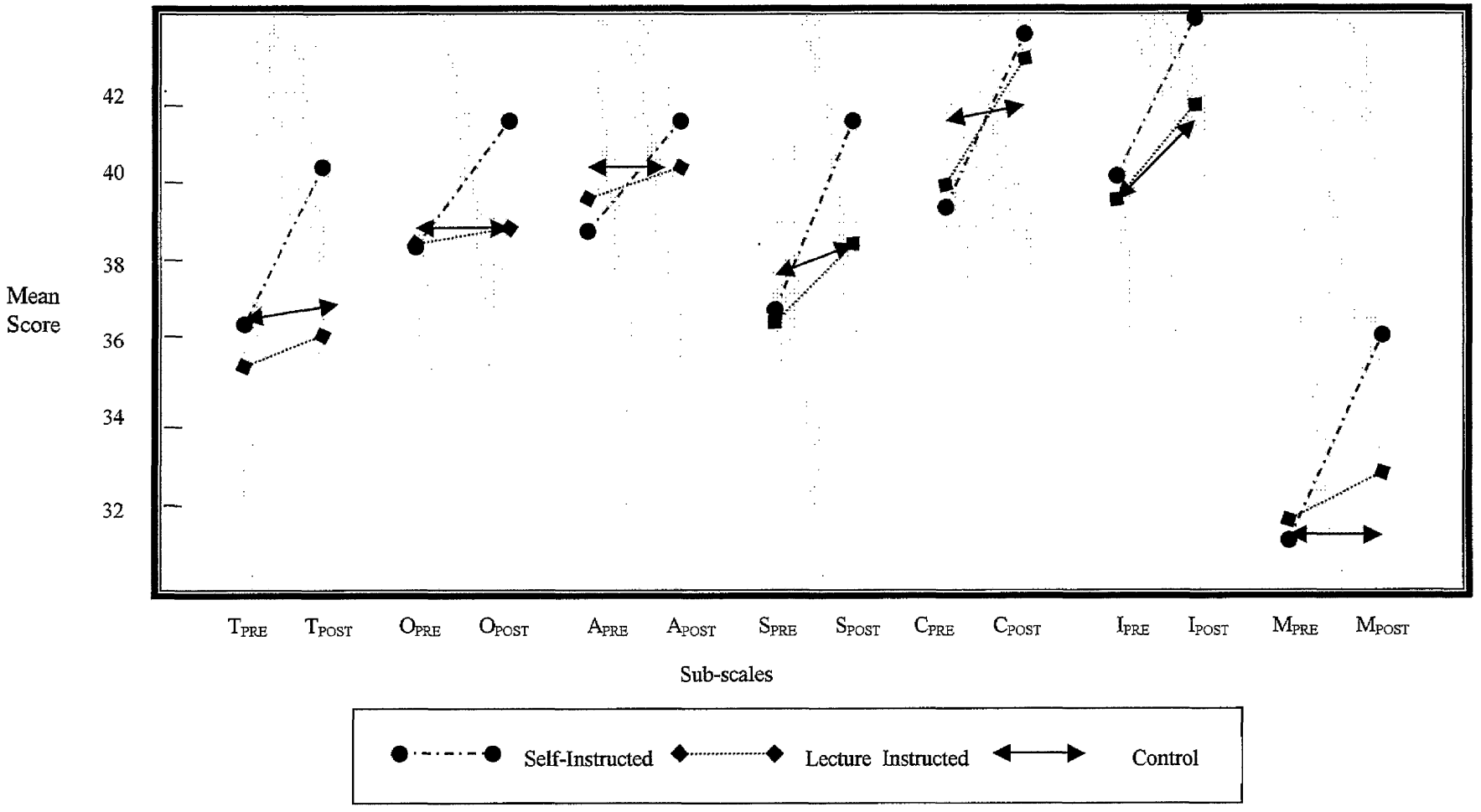


FIGURE 5.9

METHOD OF INTERVENTION STRATEGY BY SUB-SCALE INTERACTION



From FIGURE 5.8 interaction is indicated by the presence of nonparallel lines (McGuigan, 1990; Steven, 1992) representing the effect generated by the method of intervention strategy on the total CCTDI score as well as on every sub-scale of the CCTDI (see FIGURE 5.9). It is clear that the attitude of the student teachers changed noticeably after the intervention strategy. It is also apparent that the attitude changes of the student teachers in the self-instructed group is significantly greater than the level of the lecture instructed and the control group, i.e. the treatment has led to greater changes of attitude in that group than the other two groups. The interaction appears to be produced by the fact that self-instructed and lecture instructed were virtually indistinguishable before the intervention, but significantly different after the intervention strategy. The control group, on the other hand, although initially scoring slightly higher than the self-instructed and lecture instructed groups, at the end of the intervention strategy, demonstrated the lowest score of all.

Kirk (1968) and Howell (1997) argued that whenever the interaction is significant, analysis of the simple interaction effect should be made. Such an analysis has proved useful especially in terms of examining the source of main effect of method in influencing the post-test score (Al Majid, 1991). From the data in TABLE 5.18, analyses of simple interaction effects were performed on each test time; viz. pre-test and post-test, using two stage Multivariate Analysis of Variance (method X sub-scales (3 X 7)), with repeated measures on the second factor.

In the first stage (pre-test) (see TABLE 1, APPENDIX K), a significant main effect for the sub-scales is found ($F = 82.57$; $p < .05$). However, there is no significant main effect of method ($F = 1.27$; $p > .05$) and no method X sub-scales interaction was shown ($F = .64$; $p > .05$). In the second stage (post-test) (see TABLE 2, APPENDIX K), not only is the main effect of method of intervention strategy ($F = 12.00$; $p < .05$) and sub-scales ($F = 81.79$; $p < .05$) significant, but there is also significant method X sub-scales interaction ($F = 1.97$; $p < .05$). Findings from these simple interaction effect analyses suggest that the method of intervention strategy may have a

significant effect in determining the CCTDI post-test score on every sub-scale. Correspondingly, in determining the source of main effect of method and sub-scales, a series of analyses of variance followed by a Bonferroni *post hoc* test as suggested by Myers (1979) and Maxwell (1980) were conducted. Outputs presented in TABLE 3 to TABLE 10 (APPENDIX K) lead to the final conclusion that significant main effect of method is limited to the self-instructed group exclusively, and this method has a significant main effect in determining the CCTDI post-test sub-scales scores, with the only exceptions being on the Self Confidence and Analyticity scores.

5.3.5. Summary of the Findings

This section presents descriptive and inferential findings on the California Critical Thinking Disposition Inventories (CCTDI), a test which measures attitude and disposition towards critical thinking. Its main objective is to determine whether the intervention strategy specifically designed to encourage science student teachers to embed critical thinking in science instruction has successfully changed the student teachers' attitude towards critical thinking. And if the intervention strategy is empirically proven successful, whether one method makes a significant contribution towards the occurrences of such changes; viz. self-instructed or lecture instructed.

In the preliminary descriptive analysis, student teachers' critical thinking attitudinal profile before the exposure to the intervention strategy is graphically illustrated. It is shown that both groups (test and control) demonstrate an overall deficiency in their critical thinking attitudes. Further analysis of the attitudinal profile shows that such a deficiency is primarily due to their unwillingness to reconsider and revise views (Truth Seeking) coupled with their lack of determination in solving hypothetical problems and making decisions (Maturity). Such deficiencies in turn caused weaknesses in the way they approached problem solving and decision-making situations (Systematicity). What is also significant prior to the intervention strategy is that most of the student teachers' values are well informed (Inquisitiveness) and they have a strong trust in their own reasoning power (Self Confidence). Presumably, such

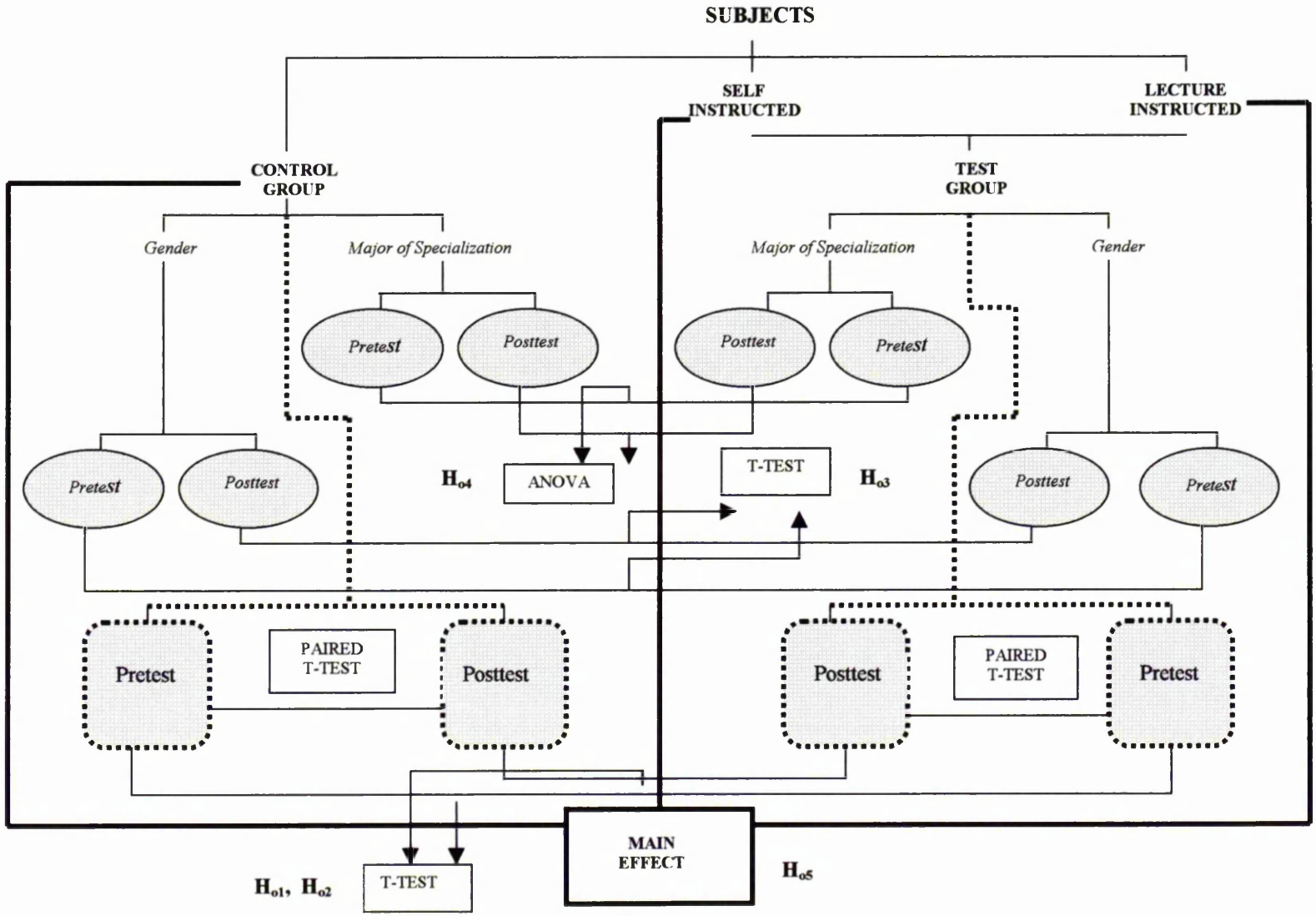
attributes are caused by their strong inclination to use fact-finding and reasoning as strategies to address serious matters (**A**nalyticity).

The relatively strong pre-existing **A**nalyticity, Self **C**onfidence and **I**nquisitiveness traits shown by the student teachers demonstrate a resistance to change as a result of the intervention strategy. The intervention did have a greater effect on student teachers' weaker attitudes prior to the intervention strategy; viz. **M**aturity, **S**ystematicity and **T**ruth Seeking. Both the test and control groups demonstrate a similar trend of changes. However, the magnitude is greater in the test group as compared to the control group.

In the inferential statistics that followed, the effectiveness of the intervention strategy in changing the student teachers' attitudinal attributes towards critical thinking is empirically tested. Five main hypotheses have been constructed and successfully tested (see FIGURE 5.10). It appears from the empirical findings that prior to the exposure of the intervention strategy, all the student teachers, despite differences in terms of gender, major of specialisation and method of intervention strategy, were almost identical in terms of their critical thinking attitudes. However, such resemblance altered after the intervention period and the alteration seem to depend on the method of intervention strategy they received. The magnitude of change is greatest in the self-instructed group, followed by the lecture instructed group and the control group demonstrates the least change.

Further exploration of the CCTDI database was carried out by performing multivariate analysis of variance followed by the analysis of simple interaction effect on both the pre-test and the post-test scores. It was shown that the self-instructed method had a strong effect in changing the student teachers' attitudes towards critical thinking particularly in the **T**ruth Seeking, **O**pen Mindedness, **S**ystematicity, **I**nquisitiveness and **M**aturity scales. However, the strong, pre-existing **A**nalyticity and Self **C**onfidence attitudes resisted change even by the self-instructed method of intervention strategy.

FIGURE 5.10: KEY PROCEDURES IN HYPOTHESES TESTING



5.4. EXPLORATION OF CRITICAL THINKING ABILITY AS MEASURED BY THE CORNELL CRITICAL THINKING TEST (CCTT), LEVEL X

In this study student teachers' critical thinking ability is measured using the Cornell Critical Thinking Test, Level X (see §4.2.1.1.). The CCTT, Level X was scored by the researcher following the procedures recommended by the publisher (Ennis, Millman and Tomko, 1985; p. 6-8). By using the "Rights-Only" method, a participant score is the number of correct responses given and no penalty is assessed for incorrect responses. Due to the objective type of the CCTT, Level X (i.e. there are correct and incorrect answers set out in a standardised multiple choice format), there is no need to have a second rater reviewing the scores. Nevertheless to ensure the accuracy, random samples of five CCTT, Level X were re-scored and no errors were detected.

5.4.1. Descriptive Findings of the CCTT, Level X

In this section, the descriptive values of student teachers' critical thinking ability as measured by the CCTT, Level X will be explored. TABLE 5.19 summarises the distribution of score with respect to experimental groups (test and control) and method of intervention strategy. Numerical values as shown in TABLE 5.19 are enhanced by the box – and – whisker plots (FIGURE 5.11); which offer graphical representation of the distribution of the scores. FIGURE 5.11 shows that there are neither outliers nor extreme values presented. The overall performance of student teachers in the CCTT, Level X ranged from 30 to 70. While a majority of the student teachers scored 46, the overall mean score was 15.8% higher (53.27). The median score, on the other hand is 2.27 points less than the mean score. These values of measure of central tendency represent a slightly positively skewed (+. 148) normal distribution. However by referring to the widely used rule of thumb (see also page 187), the score is treated as normal since its kurtosis value (-. 918) is more than –1.0.

TABLE 5.19

THE SCORE OF THE CORNELL CRITICAL THINKING TEST BY EXPERIMENTAL GROUP AND BY METHOD OF INTERVENTION STRATEGY

EXPERIMENTAL GROUP		*DESCRIPTIVE VALUE*						
		Mean	*Std. Error*	*Std. Dev.*	*Mode*	*Percentile*		
						25.00	*50.00*	*75.00*
TEST	Self-Instructed	52.20	1.55	10.39	46.00	45.00	48.00	62.00
	Lecture Instructed	51.70	1.27	8.44	49.00	44.25	50.00	58.00
	Total	51.96	1.00	9.43	46.00	45.00	49.00	61.00
CONTROL		53.24	1.10	7.13	46.00	46.00	52.00	59.00
TOTAL		**53.27**	**.76**	**8.75**	**46.00**	**46.00**	**51.00**	**59.00**

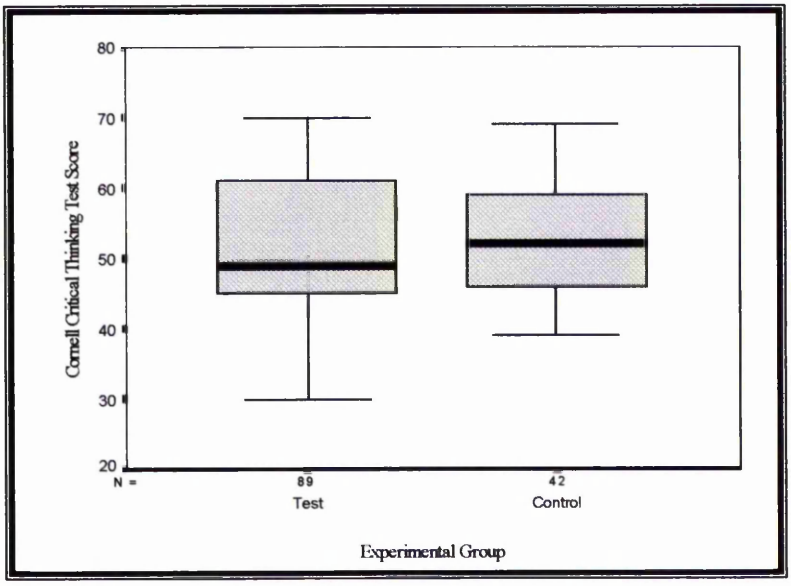
$N_{Test\ Group} = 89$; $N_{Control\ Group} = 42$

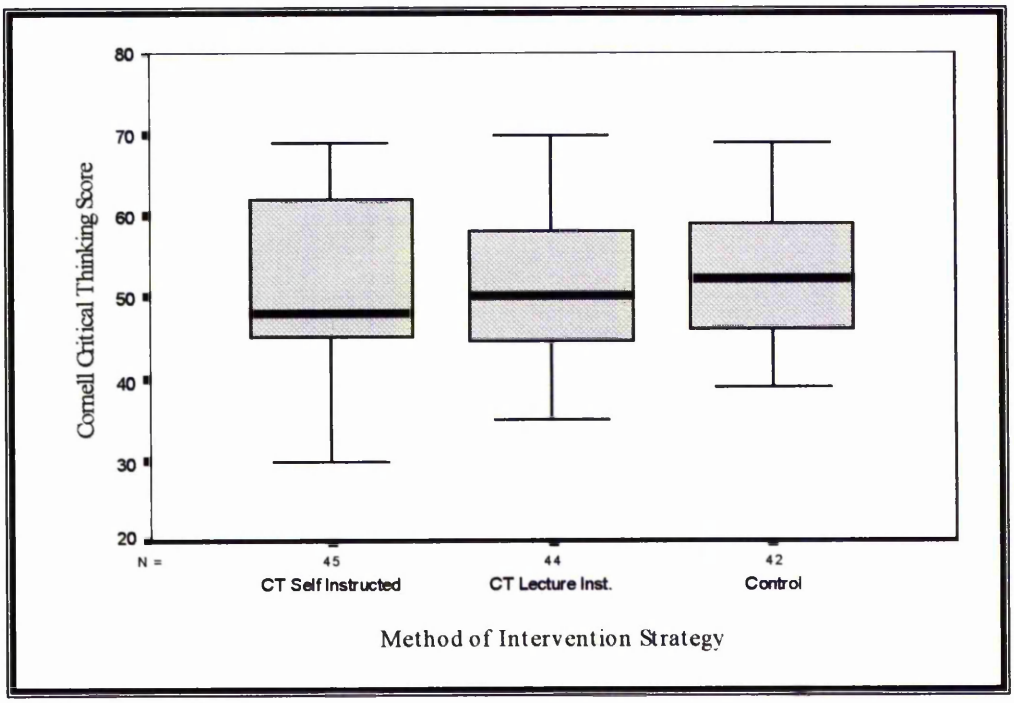
$N_{Self\text{-}Instructed} = 45$; $N_{Lecture\ Instructed} = 44$

Just like the overall score, the scores for both the test and control groups were widely distributed between their minimum (test $group_{minimum}$ = 30; control $group_{minimum}$ = 39) and maximum (test $group_{maximum}$= 70; control $group_{maximum}$ = 69) scores. Although distribution of scores in the test group was slightly bigger; which might be triggered by a bigger sample size, both the test and control groups shared the same mode score (46). However, the overall performance of the student teachers in the control group which is characterised the mean score was 2.40% higher than the test group. In terms of method of intervention strategy, the highest mean score was obtained by the control group (mean = 53.24) followed by the self-instructed group (mean = 52.20) and lecture instructed group (mean = 51.70).

FIGURE 5.11

BOX – AND WHISKERS PLOTS FOR CCTT, LEVEL X SCORE BY EXPERIMENTAL GROUPS AND METHOD OF INTERVENTION STRATEGY





5.4.2. Inferential Statistics on the CCTT, Level X

In the following the scores of the CCTT, Level X descriptively presented in §5.4.1. are empirically tested to detect differences, if any with respect to the experimental groups and method of intervention strategy. Additionally, the relationship between the CCTT, Level X and the CCTDI is tested. Considering the interval nature of the CCTT, Level X and the CCTDI scores, the strength and direction of the relationship will be gauged parametrically by applying the *Pearson correlation coefficient* (Moore and McCabe, 1993) method.

5.4.2.1. Hypothesis One

In determining whether there is a statistically significant difference in the measurable CCTT, Level X score between the test and the control group, t-test analysis is performed and the null (H_0) and alternative (H_1) hypotheses to be tested are:

H_{01} There is no significant difference in the critical thinking ability as measured by the CCTT, Level X between the test and the control group; and

H_{12} There is a significant difference in the critical thinking ability as measured by the CCTT, Level X between the test and the control group.

From TABLE 5.20, Levene's test rejects the null hypothesis that the two groups have the same population variance ($p=.023$) at the 5% level of significance. The t-statistics value that follows is -.864 and its two-tailed p-value is .390 ($p>.05$). Therefore, the null hypothesis that the two groups (test and control) have the same CCTT, Level X mean score is accepted.

TABLE 5.20

STUDENT'S T-TEST COMPARING MEANS OF THE CCTT, LEVEL X BY EXPERIMENTAL GROUPS

Variable	Number of cases	Mean	Standard Deviation	SE of Mean
CCTT, LEVEL X				
Test Group	89	51.96	9.43	1.00
Control Group	42	53.24	7.13	1.10

Levene's Test for Equality of Variances F = 5.294 P = .023

T-TEST FOR EQUALITY OF MEANS

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	-.782	129	.435	1.64	(-4.53, 1.96)
Unequal	*-.864*	*103.718*	*.390*	*1.49*	*(-4.23, 1.66)*

5.4.2.2. Hypothesis Two

With respect to the method of intervention strategy, further examination of the mean difference of the student teachers CCTT, Level X score is conducted by using the One Way Analysis of Variance (ANOVA). The hypotheses to be tested are as follows:

H_{02} There is no significant difference between the population mean of the CCTT, Level X with respect to the method of the intervention strategy; or

$$\mu_{\text{Self-Instructed}} = \mu_{\text{Lecture Instructed}} = \mu_{\text{Control}}$$

H_{12} There is some difference between the population means (i.e. they are not all the same); or

$$\mu_{\text{Self-Instructed}} \neq \mu_{\text{Lecture Instructed}} \neq \mu_{\text{Control}}$$

TABLE 5.21

ONE-WAY ANALYSIS OF VARIANCE COMPARING MEANS OF THE CCTT, LEVEL X SCORE BY METHOD OF THE INTERVENTION STRATEGY

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	2	53.424	26.217	.339	.713
Within Groups	128	9893.978	77.297		
Total	130	9946.412			

$\text{Mean}_{\text{Self-Instructed}} = 52.20$; $\text{Mean}_{\text{Lecture Instructed}} = 51.70$; $\text{Mean}_{\text{Control}} = 53.24$

The summary table (TABLE 5.21) shows that the F value of .339 is not significant at the 5 % level of significance and hence no *post hoc* test will be followed. The null hypothesis that the three groups have the same population means is then accepted. The outcomes from hypothesis one and hypothesis two further strengthened our prior contention that these groups of student teachers were drawn from the same population; identical not merely in terms of their critical thinking attitudes but also their critical thinking ability.

5.4.2.3. Hypothesis Three

The first stage of exploring the relationship between the CCTT, Level X critical thinking ability score and the CCTDI critical thinking disposition score is the generation of a scatter diagram (Campbell, 1996). Analogous to the layout of a two-way frequency table, scatter diagrams permit three aspects of relationship to be discerned; linearity, direction, and strength of the relationship (Bryman and Carter, 1990; Cohen and Holliday, 1982; Robson, 1993; Wiersma, 1969). Producing a line that fits the data closely or the line of best fit provides a further summary of the relationships between the variables involved. From FIGURE 5.12 we presume that there exists a positive linear relationship between the CCTT, Level X score and the CCTDI pre-test and post-test respectively. Under the assumptions of normality and homoscedasticity (equality in variability), we can gauge the intensity of the relationship by using the *Pearson's correlation coefficient* approach (Moore and McCabe, 1993). In measuring the strength and direction between the variables involved, the hypotheses manoeuvring the operation are as follows:

H_0 There is no positive, linear relationship between the critical thinking ability as measured by the CCTT, Level X and the critical thinking attitude as measured by the CCTDI; and

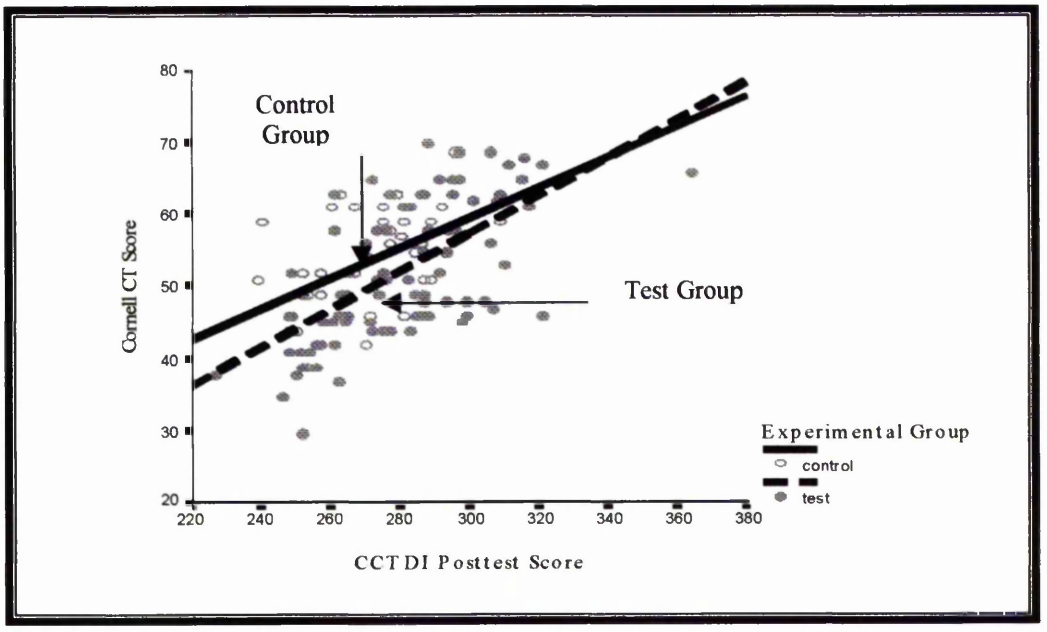
Pearson correlation coefficient = 0

H_1 There is a positive, linear relationship between the critical thinking ability as measured by the CCTT, Level X and the critical thinking attitude as measured by the CCTDI

Pearson correlation coefficient $\neq$ 0;

FIGURE 5.12

SCATTER DIAGRAM DISPLAYING THE RELATIONSHIP BETWEEN THE CCTT, LEVEL X AND THE CCTDI POST-TEST/PRE-TEST SCORES



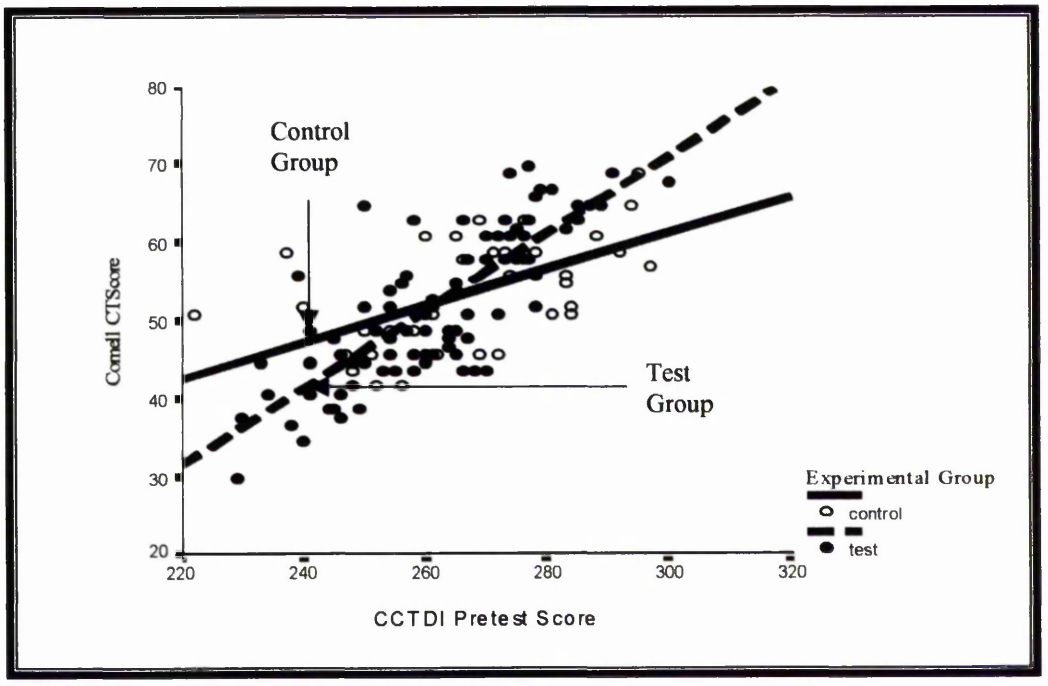


TABLE 5.22

RELATIONSHIPS BETWEEN CCTT, LEVEL X AND THE CCTDI TEST BY EXPERIMENTAL GROUPS

	EXPERIMENTAL GROUPS					
	TEST			*CONTROL*		
	Cornell	*Pre-test*	*Post-test*	*Cornell*	*Pre-test*	*Post-test*
Cornell	1.00 P=.000	.797** P=.000	.629** P=.000	1.00 P=.000	.548** P=.000	.478** P=.001
Pre-test	.797** P=.000	1.00 P=.000	.579** P=.000	.548** P=.000	1.00 P=.000	.885** P=.000
Post-test	.629** P=.000	.579** P=.000	1.00 P=.000	.478** P=.000	.885** P=.000	1.00 P=.000

** Correlation is significant at $\alpha = 0.01$

TABLE 5.22 summarises the intensity of relationships, which are symbolised by the value of *r* between the CCTT, Level X and the CCTDI pre-test and post-test by experimental groups. TABLE 5.22 verifies the prior presumption that there exists a positive linear relationship between the CCTT, Level X score and the CCTDI pre-test and post-test scores. The highest magnitude of *r* (*Pearson correlation coefficient*) is shown by a relationship between the CCTT, Level X score and the CCTDI pre-test score of the test group. The lowest magnitude of *r* is demonstrated by a relationship between the CCTT, Level X score and the CCTDI post-test score of the control group. Nevertheless, all the correlations are significant at .001 level of significance and hence the null hypothesis is strongly rejected in favour of the alternative hypothesis that there is a positive, linear relationship between the CCTT, Level X and CCTDI. Interestingly, for both groups the magnitude of *r* symbolising the relationship between the CCTT, Level X and the CCTDI pre-test score is relatively larger than the relationship between the CCTT, Level X and the CCTDI post-test score.

Related to the value of r is the coefficient of determination (r^2 X 100), which provides indices of how far variation in the CCTT, Level X is accounted for by the CCTDI pre-test and post-test scores (Cohen and Holliday, 1982; Howell, 1997). 63.5% ($.797^2$ X 100) and how far the variability of the CCTT, Level X scored by the student teachers in the test group is attributed to the CCTDI pre-test score. However, the variation in the CCTT, Level X is attributed by the CCTDI post-test score by only 39.5% ($.629^2$ X 100). The influence of the CCTDI pre-test and post-test scores on the CCTT, Level X score in the control group is relatively smaller than in the test group. The CCTT, Level X score is attributable to the CCTDI pre-test and post-test score only by 30.0% (.548 X 100) and 22.8% (.478 X 100) respectively (see FIGURE 5.13).

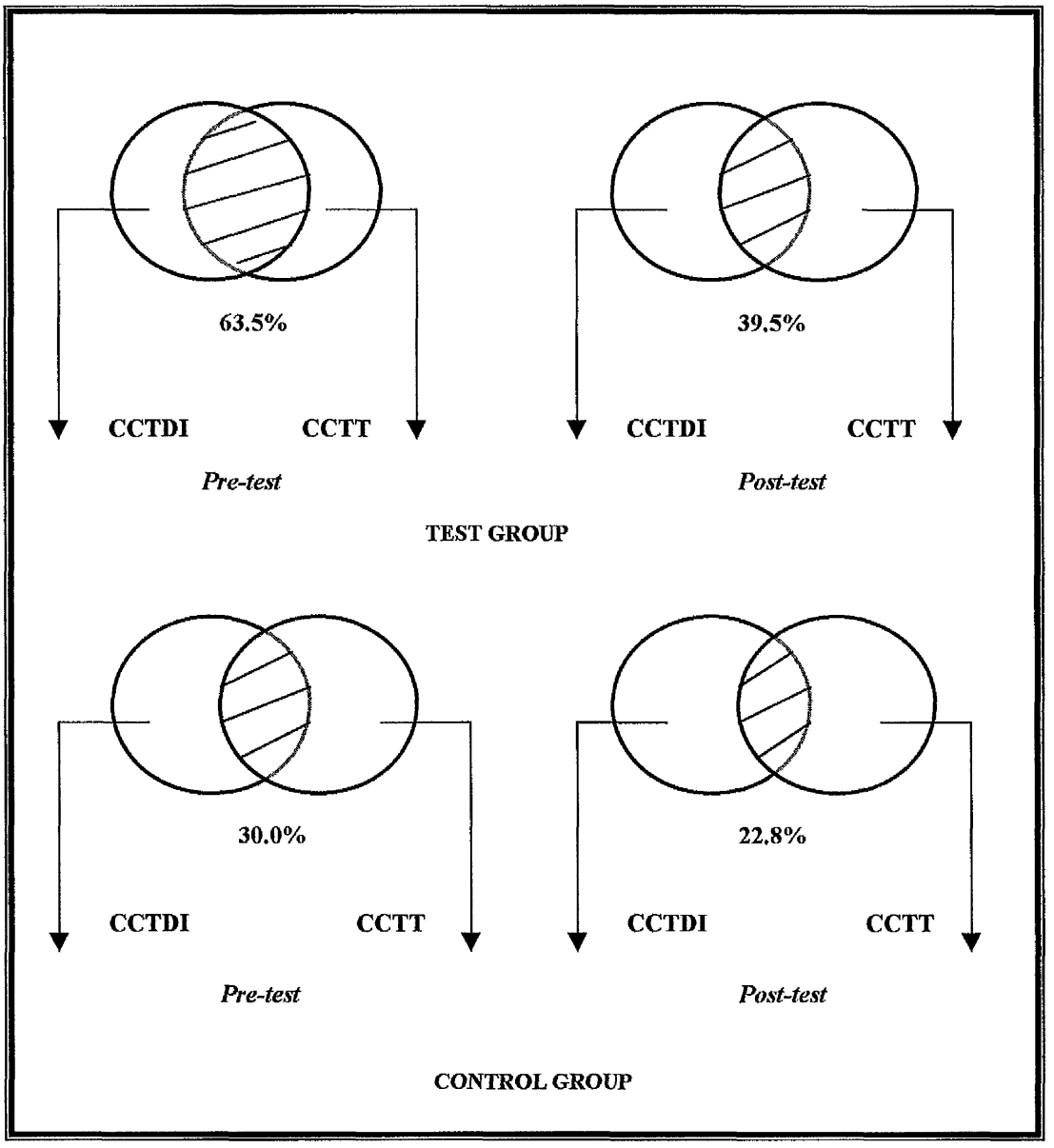
5.4.3. Summary of the Findings on the CCTT, Level X

In this section, the student teachers' critical thinking ability is explored, as is the relationship between critical thinking ability and critical thinking dispositions. Findings from the preliminary descriptive analysis on the CCTT, Level X found that although the maximum score reaches 70, the overall mean was only 53.27. When scores are compared according to the method of intervention strategy, the highest mean is obtained by the control group (53.24), followed by those in the self-instructed group and the lecture instructed group with mean scores of 52.20 and 51.70 respectively. However, inferential statistics on these mean scores found no differences regardless of experimental group or method of intervention strategy.

Exploration of the relationship between critical thinking ability and critical thinking dispositions by means of scatter diagrams allow the conclusion that there is a linear relationship between critical thinking ability and critical thinking disposition (pre-test and post-test). The strength of this relationship is measured by the *Pearson correlation coefficient*. The outcomes show that despite the differences in terms of strength of the relationship, there exist positive, linear relationships between critical

FIGURE 5.13

COEFFICIENTS OF DETERMINATION BETWEEN THE CCTT, LEVEL X AND THE CCTDI



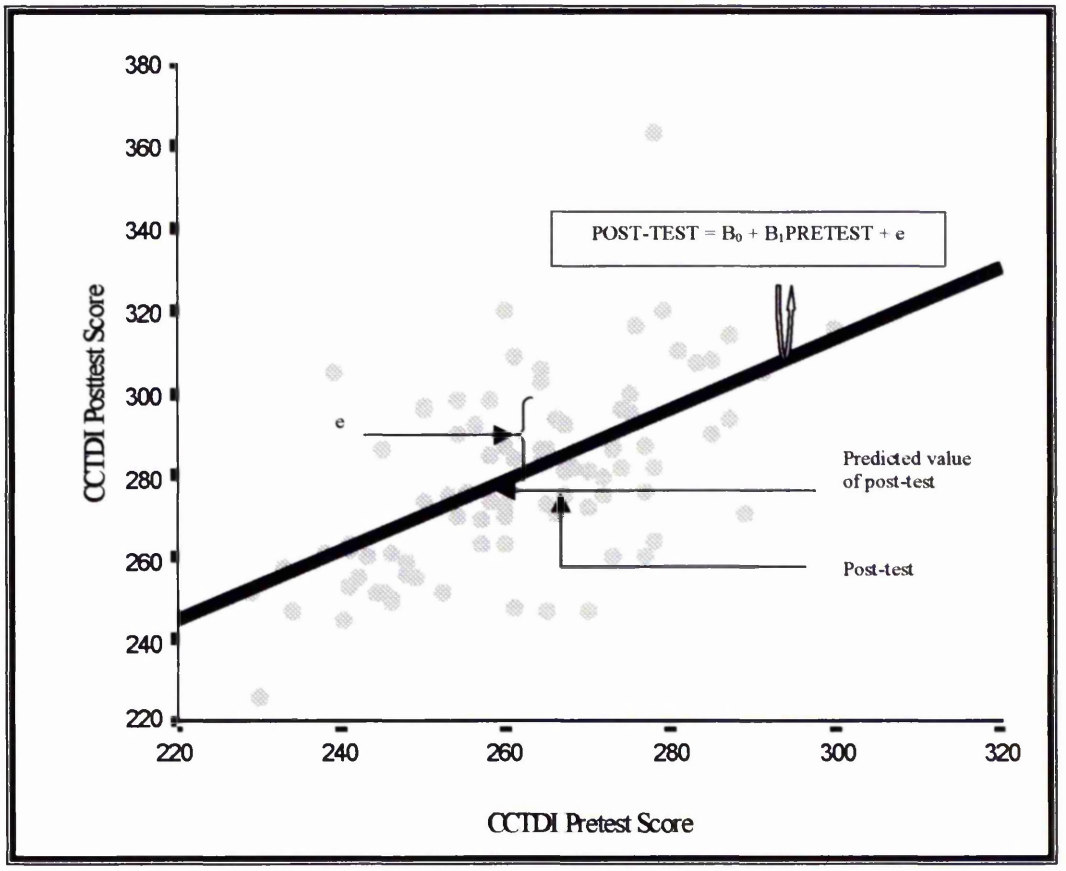
thinking ability and critical thinking pre-test and post-test disposition scores. A fuller grasp of the correlation is gained by considering the coefficients of determination; a value which determines what percentage of total variance of the CCTT, Level X is due to the variance of the CCTDI. Comparisons of the magnitude of the coefficient of determination reveal that the variability in the CCTT, Level X accounted for by the CCTDI is lower in the post-test score than it is in the pre-test score. The reduction percentage is even greater in the test group (37.8%) than in the control group (24%).

The student teachers in this study, although being segregated in terms of experimental groups and method of intervention strategy, are identical, not merely in terms of their critical thinking attitudes, but also their critical thinking ability. Such homogeneity of student teachers increases the internal validity of this *quasi-experimental* study. Additionally, the relationship between the critical thinking ability and critical thinking attitudes implies that student teachers with stronger affective attitudinal dimensions, will also have stronger cognitive power when operating critical thinking tasks.

5.5. PREDICTIVE RELATIONSHIP BETWEEN THE CCTDI PRE-TEST AND THE POST-TEST

As indicated in TABLE 5.22, there is a strong positive relationship between the CCTDI pre-test and post-test scores. FIGURE 5.14 depicts the relationship between the CCTDI post-test and pre-test score symbolised by the magnitude of r = 0.58 (see TABLE 5.22). The presence of the *line of goodness fit* or *regression line,* which is drawn to describe the average relationship between the CCTDI pre-test and post-test score, strengthens the assumption of positive linear relationships between the two variables. Further analyses of the statistical behaviour of the relationship found that it met all the requirements of performing the linear regression analysis (i.e. uncorrelated residuals for successive cases, normality and equality of variance of the residuals). Since it is permissible to employ regression analysis, the next section tests whether the score of the pre-test could be used as a predictor of the post-test score of the student teachers, exclusively those in the test group.

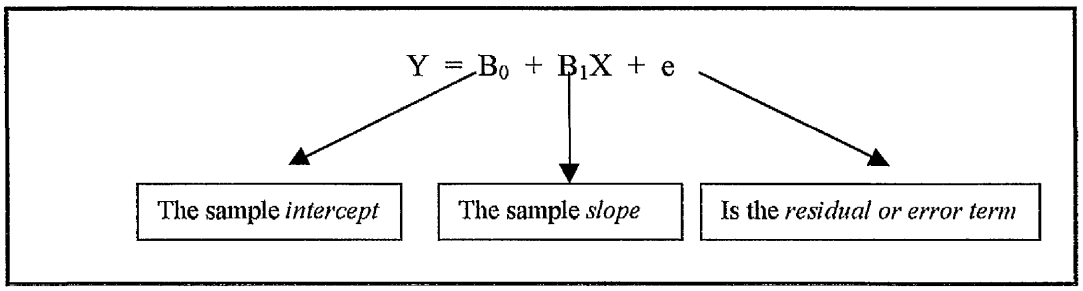
FIGURE 5.14
SCATTER DIAGRAM DISPLAYING RELATIONSHIP BETWEEN THE CCTDI POST-TEST AND THE PRE-TEST SCORE



5.5.1. Hypothesis One

The application of knowledge from the field of elementary geometry provides us with the basic theoretical framework in regression analysis. Any straight line through a set of points on a graph can be defined by a mathematical equation in the form of Y = a + bX; where a is the intercept on the Y axis and b is the slope of the line. It follows that when the value of a and b are known, we can predict the value of Y from any particular value of X. Generally the predicted variable (Y) is known as the dependent variable and the predictor (X) as the independent variable. This

mathematical relationship between X and Y is represented in the regression equation or linear model for sample values of X and Y in the form of:



B_0 and B_1 are called *regression coefficients*. In this case under consideration a prediction of the value of the CCTDI post-test from the value of the CCTDI post-test is:

$$\text{POST-TEST} = B_0 + B_1\text{PRE-TEST} + e$$

and the null hypotheses are:

H_0 : $R^2 = 0$ or there is no significant linear relationship between the CCTDI pre-test and post-test score; and

H_0 : B_0 and $B_1 = 0$ or there is no significant predictive relationship between the CCTDI pre-test and post-test score.

TABLE 5.23 summarises the results of regression analysis. The first part of TABLE 5.23 gives the value of R (sample correlation coefficient) which magnitude tells us how strongly points are clustered about the fitted regression line. Connected to R is R^2 (sample coefficient of determination) or a key *goodness-of-fit* statistic, which is used as an indicator of the proportion of the variation in the CCTDI post-test scores explainable by the CCTDI pre-test scores. From the R^2 value = 0.335, we know that 33.5% of variation in the CCTDI post-test score is attributed by the variation in the CCTDI pre-test score; i.e. there exists a positive linear relationship between the two. In order to confirm this conclusion, reference should be made to the ANOVA table. The p-value of .000 corresponds to value of F = 43.806 confirming that the null hypothesis of no linear relationship (i.e. no linear regression) is very strongly rejected.

TABLE 5.23

SIMPLE REGRESSION OUTPUT

Variable	*R*	*R Square*	*Adjusted R Square*	*Standard Error*
Pre-test Score	.579	.335	.327	18.48

REGRESSION ANALYSIS OF VARIANCE TABLE

	DF	*Sum of Squares*	*Mean Square*
Regression	1	14956.7	14956.7
Residual	87	29704.2	341.28
Total	88	44660.9	

F = 43.806 Sig. F = .000

REGRESSION T-TEST TABLE
(with constant term dropped)

	B	*Std. Error*	*Beta*	*t*	*Sig.*
Pre-test Score	1.07	.008	.998	141.744	.000*

*significant at α = .05

The Significant ANOVA indicates *a priori*, the value of the regression coefficients (B_0 and B_1) for the CCTDI pre-test is non-zero. However, the significant t-test value is only shown on B_1 ($t= 6.619$, $p< .000$) while the p-value B_0 is far greater than 0.05. Thus, regression analysis is repeated without a constant term and the resulting B_1 value is 1.07. Finally a highly significant linear fit is produced and the new regression model is as follows:

POST-TEST = 1.07 PRE-TEST

The estimated value of the CCTDI post-test scores within the range of 220 to 320 for the two models are shown in TABLE 5.24. When these estimated post-test scores are compared with the actual post-test values, the error of prediction is less than 15, even with the extreme observations. Therefore, the model of regression equation generated in this study could be used as a means of predicting the total post-test scores of the student teachers; a score which indicates attitudinal changes towards critical thinking.

TABLE 5.24
ESTIMATED VALUE OF THE CCTDI POST-TEST SCORE FOR A GIVEN CCTDI PRE-TEST SCORE

Pre-test Score	220	240	260	280	300	320
Estimated Post-test Score	*235*	*257*	*278*	*300*	*321*	*342*

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5.5.2. Hypothesis Two

TABLE 5.25
INTERCORRELATION MATRIX

	Post-test	T_{pre}	O_{pre}	A_{pre}	S_{pre}	C_{pre}	I_{pre}	M_{pre}
Post-test	1.00 p=.	.283** p=.007	.263* p=.013	.293** p=.005	.495** p=.000	.140 p=.192	.451** .000	.302** p=.004
T_{pre}	.283** p=.007	1.00 p=.	.215* p=.043	.129 p=.230	.392** p=.000	-.179 p=.093	.120 p=.263	.249* p=.019
O_{Pre}	.263* p=.013	.215* p=.043	1.00 p=.	.211* p=.047	.247* p=.020	-.089 p=.408	.132 p=.219	.091 p=.398
A_{pre}	.293** p=.005	.129 p=.230	.211* p=.047	1.00 p=.	.367** p=.000	.417** p=.000	.361** p=.001	.054 p=.618
S_{pre}	.495** p=.000	.392** p=.000	.247* p=.020	.367** p=.000	1.00 p=.	.054 p=.617	.289** p=.006	.203 p=.056
C_{pre}	.140 p=.192	-.179 p=.093	-.089 p=.408	.417** p=.000	.054 p=.617	1.00 p=.	.282** p=.008	-.075 p=.482
I_{pre}	.451** .000	.120 p=.263	.132 p=.219	.361** p=.001	.289** p=.006	.282** p=.008	1.00 p=.	.267* p=.011
M_{pre}	.302** p=.004	.249* p=.019	.091 p=.398	.054 p=.618	.203 p=.056	-.075 p=.482	.267* p=.011	1.00 p=.

** Correlation is significant at $\alpha = 0.01$ * Correlation is significant at $\alpha = 0.05$

Analysis in the previous section has shown that there exist a significant predictive linear relationship between the pre-test and the post-test. The ratio between the sample size (n=89) and the numbers of predictors (7) of nearly 15 (Steven, 1992) allows us to further examine which of the pre-test sub-scales contribute a significant predictive power in determining the value of the post-test score. The involvement of more than one-predictor variables transformed the previous simple regression equation into:

$$Y = B_0 + B_1X_1 + B_2X_2 + \ldots B_kX_k + e$$

Where B_0 is the intercept and B_1, B_2, and B_k are known as the partial regression coefficient. Therefore, the linear model will be:

POST-TEST= B_0 + B_1T_{Pre} + B_2 O_{Pre} + B_3 A_{Pre} + B_4S_{Pre}+ B_5C_{Pre} + B_6 I_{Pre} + $_7M_{Pre}$+ e

and the null hypotheses to be tested are:

H_0 : $R^2 = 0$ or there is no significant linear relationship between the post-test score and best linear combination of the predictors; and

H_0 : B_0 ,B_1, B_2 ,B_3, B_4 ,B_5, B_6 ,B_7= 0 or there is no significant predictive relationship between the predictors and post-test score.

The inter-correlation matrix (TABLE 5.25) gives us prior information about the validity; a measure to which the predictors could be used as a valid predictor of the criterion. From the TABLE 5.25, it is apparent that the validity of **S**ystematicity is the highest among all (r=4.95; p<.01). In terms of collinearity (correlation with other variables) the **A**nalyticity scale demonstrates a high collinearity with several other variables. Therefore, when all the variables are included as a predictor, even if the regression output tells us that 39.0% of the variation in the overall post-test score is due to the combined effect of the seven predictors, **A**nalyticity will have no unique individual contribution in explaining the variability in the overall rating. From the regression output (TABLE 5.26), the model of regression equation is as follows:

POST-TEST = 0.781 T_{Pre}+ 1.26 O_{Pre} + .12 A_{Pre} + 2.22 S_{Pre} + .66 C_{Pre} + 1.72 I_{Pre} + .70M_{Pre}

From the equation, it could be expected that if a student teacher scored only one point higher than another student on the **S**ystematicity scale, the possibility that they would change their attitude towards critical thinking is high. Conversely, for those who score one point higher in the **A**nalyticity scale, their chances of changing their attitude towards critical thinking will be trivial.

TABLE 5.26

MULTIPLE REGRESSION ANALYSIS

Variable	*R*	*R Square*	*Adjusted R Square*	*Standard Error*
T_{Pre}, O_{Pre}, A_{Pre}, S_{Pre}, C_{Pre}, I_{Pre}, M_{Pre}	.625	.390	.338	18.33

REGRESSION ANALYSIS OF VARIANCE TABLE

	DF	*Sum of Squares*	*Mean Square*
Regression	7	17436.1	2490.875
Residual	81	27224.8	336.109
Total	88	44660.9	

F = 7.411 Sig. = .000

REGRESSION T-TEST TABLE
(with constant term dropped)

	B	*Std. Error*	*Beta*	*t*	*Sig.*
Truth Seeking	.781	.563	.101	1.389	.169
Open	1.258	.544	.173	2.312	.023*
Mindedness	.121	.673	.017	.180	.857
Analyticity	2.220	.661	.292	3.359	.001*
Systematicity	.661	.435	.094	1.520	.132
Self Confidence	1.721	.566	.246	3.040	.003*
Inquisitiveness	.701	.409	.079	1.715	.090
Maturity					

* significant at $\alpha = .05$

5.5.3. Summary of the Findings on the Predictive Relationship between CCTDI Pre-test and Post-test Score

Findings from the simple regression analysis show that when the student teachers were exposed to the intervention strategy which encourages them to embed critical thinking in science instruction, their pre-test scores could be used as a predictor of the post-test scores. The output from multiple regression analysis reveals that the student teachers' score in the CCTDI post-test is heavily dependent on the **S**ystematicity score; viz. their disposition towards organised, orderly, focused, and diligent enquiry. **A**nalyticity and Self **C**onfidence scores affect the CCTDI post-test score least.

It could be argued that the relatively small contribution of **A**nalyticity and Self **C**onfidence is due to the fact that these two attitudes are already highly established and hence more resistant to change regardless of intervention strategy. On the other hand, **S**ystematicity, **I**nquisitiveness, **O**pen Mindedness, **T**ruth Seeking and **M**aturity are the attributes which changed significantly after the intervention strategy. As shown in the analysis of the main effect earlier, the intervention strategy has caused significant changes in those five attributes and no significant changes on the **A**nalyticity and Self **C**onfidence ones. Therefore, the student teachers' score in those two attributes could not be used as a guideline in predicting changes in their overall attitudes towards critical thinking after the intervention strategy.

5.6. ANALYSIS OF THE EVALUATION TEST (TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE)

Teachers' knowledge and understanding of the key aspects of critical thinking in the science classroom are measured by the evaluation test, specifically constructed and designed by the researcher (see §4.2.3). Its main function is as a terminal evaluation of the student teachers' cognitive status on the completion of the intervention strategy. Developed in line with Bloom's Taxonomy of Educational Objectives, the evaluation test concentrates on the first three levels of the taxonomy; knowledge, comprehension and application. Constructed in a standardised multiple-choice form, the evaluation test is composed of 15 items (see APPENDIX E). In the next segment, the descriptive analysis and inferential statistical analysis of the results will be conducted in seeking differences, if any, with respect to the experimental groups and method of intervention strategy. Analysis of main effect is followed by simple effect interaction analyses.

5.6.1. Descriptive Findings of the Evaluation Test

The performance of the test group (mean = 13.47) on the total evaluation score as well as on the sub-domains of the evaluation score is higher compared to the control group (mean = 11.12) (see TABLE 5.27). Detailed analysis of the evaluation scores yields a reverse effect with the level of cognitive operations. The increase of the level of cognitive operations was followed by a decrease of the evaluation scores. Both groups demonstrate a similar scoring pattern. The highest scores were obtained in the lowest knowledge level of cognitive operations knowledge and the lowest scores were obtained in the application level of cognitive operations.

In terms of method of intervention strategy, the highest total means score is obtained by the self-instructed group, followed by the lecture instructed and control group. Additionally, the lowest value of standard deviation following the total mean score indicates that the variance of score in the self-instructed group is small, a great

majority scoring near the mean score. Just like the total mean score, the student teachers' mean score in the knowledge, comprehension and application cognitive levels also reflects this same pattern of score. Their score is the highest at the knowledge level and lowest at the application level.

TABLE 5.27

THE SCORE OF THE EVALUATION TEST BY EXPERIMENTAL GROUPS

EXPERIMENTAL GROUP		*EVALUATION TEST*						*TOTAL*	
		Knowledge		*Comprehension*		*Application*			
		Mean	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*
TEST	Self-instructed	4.96	.21	4.71	.46	4.24	.65	13.91	.87
	Lecture Instructed	4.80	.41	4.48	.55	3.75	.75	13.02	1.15
	Total	4.88	.33	4.60	.52	4.00	.74	13.47	1.11
CONTROL		4.45	.63	3.57	.74	3.10	.66	11.12	1.02
TOTAL		4.74	.49	4.27	.76	3.71	.83	12.72	1.54

$N_{\text{Test Group}} = 89$; $N_{\text{Control Group}} = 42$

5.6.2. Hypothesis One

Following the result in TABLE 5.27 an independent sample t-test was performed in order to test the following null (H_0) and alternative (H_1) hypotheses:

H_{01} There is no significant difference in the measurable evaluation test of the experimental groups (test and control) after exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science teaching; and

H_{11} There is significant difference in the measurable evaluation test of the experimental groups (test and control) after exposure to an intervention strategy designed to encourage student teachers to embed critical thinking in their science teaching.

TABLE 5.28 shows a mean difference of 2.35 between the groups produced a significant difference between the two groups at the 5% level of significance ($t=11.63$; $p<.005$). Therefore, the null hypothesis that the two groups have the same population means is rejected in favour of the alternative hypothesis that there exists a significant difference between the groups in terms of their evaluation test mean score. The test group scores significantly higher at all levels than the control group.

TABLE 5.28

STUDENT'S T-TEST COMPARING MEANS OF THE EVALUATION TEST BY EXPERIMENTAL GROUPS

Variable	*Number of cases*	*Mean*	*Standard Deviation*	*SE of Mean*
EVALUATION TEST				
Test Group	89	13.47	1.11	.12
Control Group	42	11.12	1.02	.16

Levene's Test for Equality of Variances F = 2.591 P = .110

T-TEST FOR EQUALITY OF MEANS

Variances	**t-value**	**df**	**2-Tail Sig**	**SE of Diff**	**95% CI for Diff**
Equal	*11.633*	*129*	*.000* *	*.20*	*(1.95, 2.75)*
Unequal	12.001	87.123	.000	.20	(1.96, 2.74)

* significant at $\alpha = .05$

5.6.3. Hypothesis Two

Scoring distribution data in TABLE 5.27 and preliminary t-test results (TABLE 5.28) show that there exists a significant difference in the mean evaluation test between the test and control group. The mean difference with regards to the method of intervention strategy can be determined by using the One Way Analysis of Variance (ANOVA) and the hypotheses are:

H_0 There is no significant difference between the population mean of the evaluation score with respect to the method of intervention strategy; or

$$\mu_{\text{Self-Instructed}} = \mu_{\text{Lecture Instructed}} = \mu_{\text{Control}}$$

H_1 There is some difference between the population mean (i.e. they are all not the same; or

$$\mu_{\text{Self-Instructed}} \neq \mu_{\text{Lecture Instructed}} \neq \mu_{\text{Control}}$$

TABLE 5.29

ONE-WAY ANALYSIS OF VARIANCE COMPARING MEANS OF THE EVALUATION TEST SCORE BY METHOD OF THE INTERVENTION STRATEGY

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	2	175.523	87.762	84.445	.000*
Within Groups	128	133.026	1.039		
Total	130	308.550			

* significant at $\alpha = .05$

The summary table above (TABLE 5.29) shows that the F value of 84.445 is significant at the 5% level of significance. Therefore the null hypothesis that the three groups have the same population mean evaluation score is rejected in favour of the alternative hypothesis that there is some significant difference between the population means. Although the F value reveals that there is a significant difference between the method of intervention strategy, it does not tell us if all the differences are significant (but only that at least one significant difference exists). The differences between the means score of the three methods are then examined using the Scheffe *post hoc* analysis. Results show that the three means are significantly

different upon one another each at the 5% level of significant (see TABLE 1, APPENDIX L).

5.6.4. Hypothesis Three

In §5.6.3 and §5.6.4, the results show that there is a significant difference in the evaluation score between the test and the control group. In determining whether the student teachers' score in the evaluation test is dependent upon their critical thinking attitude, a series of correlational analyses is conducted. The strength and direction of the relationship between the critical thinking attitude as measured by the CCTDI and the score of the evaluation test is gauged by using the *Pearson correlation coefficient* approach. The hypotheses are:

H_{03} There is no positive, linear relationship between the critical thinking attitude as measured by the CCTDI (pre-test/post-test) and score of the evaluation test (knowledge, comprehension and application) in the test and control group; and

H_{13} There is a positive, linear relationship between the critical thinking attitude as measured by the CCTDI (pre-test/post-test) and score of the evaluation test (knowledge, comprehension and application) in the control group.

TABLE 5.30 summarises the interrelationship between pre-test, post-test and the evaluation scores (knowledge, comprehension and application) for the test and the control groups. What is significant is the relationship between every level of evaluation score (knowledge, comprehension and application) with the total evaluation score. However, a positive linear relationship is only shown between the application score and the CCTDI post-test score of the test group. At the knowledge and comprehension levels of cognitive operation, neither CCTDI pre-test nor post-test affect the student teachers' score. From the value of r, it could be implied that at

least 6.25% variability in the application score of the student teachers in the test group is due to the variance of their CCTDI post-test score.

TABLE 5.30

RELATIONSHIPS BETWEEN THE CCTDI TEST AND THE EVALUATION TEST BY EXPERIMENTAL GROUPS

		Pre-test	Post-test	Know	Comp	Apply	Total
Test	Pre-test	1.00 p=.	.579** p=.000	-1.41 p=.188	.019 p=.863	.062 p=.561	.008 p=.940
	Post-test	.579** p=.000	1.00 p=.	-.092 p=.389	.117 p=.275	.250* p=.018	.193 p=.069
	Know	-1.41 p=.188	-.092 p=.389	1.00 p=.	.170 p=.112	.046 p=.665	.408** p=.000
	Comp	.019 p=.863	.117 p=.275	.170 p=.112	1.00 p=.	.298 p=.005	.715** p=.000
	Apply	.062 p=.561	.250 p=.018	.046 p=.665	.298 p=.005	1.00 p=.	.819** p=.000
	Total	.008 p=.940	.193 p=.069	.408** p=.000	.715** p=.000	.819** p=.000	1.00 p=.
Control	Pre-test	1.00 p=.	.885** p=.000	.170 p=.283	.095 p=.552	.093 p=.557	.234 p=.136
	Post-test	.885** p=.000	1.00 p=.	.216 p=.169	.073 p=.648	.050 p=.751	.220 p=.162
	Know	.170 p=.283	.216 p=.169	1.00 p=.	-.149 p=.345	-.048 p=.765	.483** p=.001
	Comp	.095 p=.552	.073 p=.648	-.149 p=.345	1.00 p=.	-.166 p=.294	.525** p=.000
	Apply	.093 p=.557	.050 p=.751	-.048 p=.765	-.166 p=.294	1.00 p=.	.495** p=.001
	Total	.234 p=.136	.220 p=.162	.483** p=.001	.525** p=.000	.495** p=.001	1.00 p=.

** Correlation is significant at $\alpha = 0.01$

* Correlation is significant at $\alpha = 0.05$

$N_{Test} = 89$

$N_{Control} = 42$

5.6.5. Hypothesis Four

TABLE 5.31

EVALUATION TEST SCORES BY METHOD OF INTERVENTION STRATEGY BY MAJOR OF SPECIALISATION

Met \ Major		PHYSICS			CHEMISTRY			BIOLOGY			MATH			TOTAL		
		K	*C*	*A*	*K*	*C*	*A*	*K*	*C*	*A*	*K*	*C*	*A*	*K*	*C*	*A*
Self-Inst.	*Min*	5.00	4.83	4.00	4.91	4.73	4.64	5.00	4.80	4.33	4.92	4.54	3.92	4.96	4.71	4.24
	SD	.00	.41	.63.	.30	.47	.50	.00	.41	.72	.28	.52	.49	.21	.46	.65
Lecture Inst.	*Min*	4.88	4.50	3.88	4.89	4.33	3.67	4.67	4.53	3.87	4.83	4.50	3.58	4.80	4.48	3.75
	SD	.35	.53	.83	.33	.71	.87	.49	.52	.74	.39	.52	.67	.41	.55	.75
Control	*Min*	4.67	3.50	3.17	4.45	3.36	3.09	4.08	3.85	3.15	4.75	3.50	3.00	4.45	3.57	3.10
	SD	.52	.84	.75	.69	.67	.70	.64	.69	.69	.45	.60	.63	.63	.74	.66
Total	*Min*	4.85	4.30	3.70	4.74	4.13	3.81	4.60	4.42	3.81	4.84	4.19	3.51	4.74	4.27	3.71
	SD	.37	.80	.80	.51	.85	.95	.58	.66	.85	.37	.78	.69	.49	.76	.83

Analysis of the main effect of method and major of specialisation upon student teachers' achievement in every cognitive level of the evaluation score is conducted by using the Multivariate Analysis of Variance with two between (method and major of specialisation) and one within subject (evaluation score) factors. TABLE 5.31 illustrates the 3 X 4 X 3 design with repeated measures on the third factor and the output is summarised in TABLE 5.32. Following are the null hypotheses to be tested in the 3 X 4 X 3 designs:

H_{04} There is no significant main effect of method of intervention strategy/major of specialisation/evaluation score;

There is no significant method of intervention strategy by major of specialisation interaction effect;

There is no significant method of intervention strategy by evaluation interaction effect;

There is no significant major of specialisation by evaluation score interaction effect; and

There is no significant method by major of specialisation by evaluation score interaction effect.

TABLE 5.32

MULTIVARIATE ANALYSIS OF VARIANCE FOR TWO BETWEEN (METHOD AND MAJOR) AND ONE WITHIN SUBJECT (EVALUATION SCORE) FACTORS

TEST OF BETWEEN SUBJECT EFFECTS

SOURCE OF VARIATION	SS	DF	MS	F	SIG. OF F
WITHIN CELL	41.83	119	.35		
METHOD	51.80	2	25.90	73.69	.000*
MAJOR	.32	3	.17	.49	.688
METHOD X MAJOR	1.92	6	.32	.91	.490

TEST INVOLVING "EVALUATION SCORE" WITHIN SUBJECT EFFECTS

SOURCE OF VARIATION	SS	DF	MS	F	SIG. OF F
WITHIN CELLS	77.88	238	.33		
EVALUATION SCORE	67.48	2	33.74	103.11	.000*
METHOD X EVALUATION SCORE	6.97	4	1.74	5.32	.000*
MAJOR X EVALUATION SCORE	4.60	6	.77	2.34	.032*
METHOD X MAJOR X EVALUATION SCORE	3.50	12	.29	.89	.557

*siginificant at $\alpha = .05$

The summary of results is presented in TABLE 5.32 and shows that only the main effect of method of intervention strategy ($F = 73.69$; $p<.05$) and evaluation score ($F=103.11$; $p<.05$) is significant at 0.05 level of significance. First order interaction effects are significant for method of intervention strategy by evaluation score ($F=5.32$; $p<.05$) and major of specialisation by evaluation score ($F=2.34$; $p<.05$). FIGURE 5.15 and FIGURE 5.16 plot the interaction between method of intervention strategy and evaluation score, and interaction between method and evaluation score as a function of major of specialisation respectively.

From FIGURE 5.15, the interaction between method of intervention strategy and evaluation test is demonstrated by the presence of nonparallel lines representing the effect generated by the method of intervention strategy on the evaluation score. Additionally, when the description of the interaction is made as a function of major of specialisation, significant interaction effect between major of specialisation and evaluation score is also significant (see FIGURE 5.16). As has been described earlier in this section, and as it is explicitly illustrated in FIGURE 5.15, the student teachers in the self-instructed group obtained the highest score in every level of cognitive operations (knowledge, comprehension and application), followed by those in the lecture instructed group. The control group demonstrates the lowest score in every level of cognitive operation (knowledge, comprehension and application). All groups produce a similar achievement pattern. The highest score is gained at the knowledge level of cognitive operation, followed by the comprehension level and the lowest score is obtained at the application level of cognitive operation.

FIGURE 5.15

THE INTERACTION BETWEEN METHOD OF INTERVENTION STRATEGY AND EVALUATION SCORE

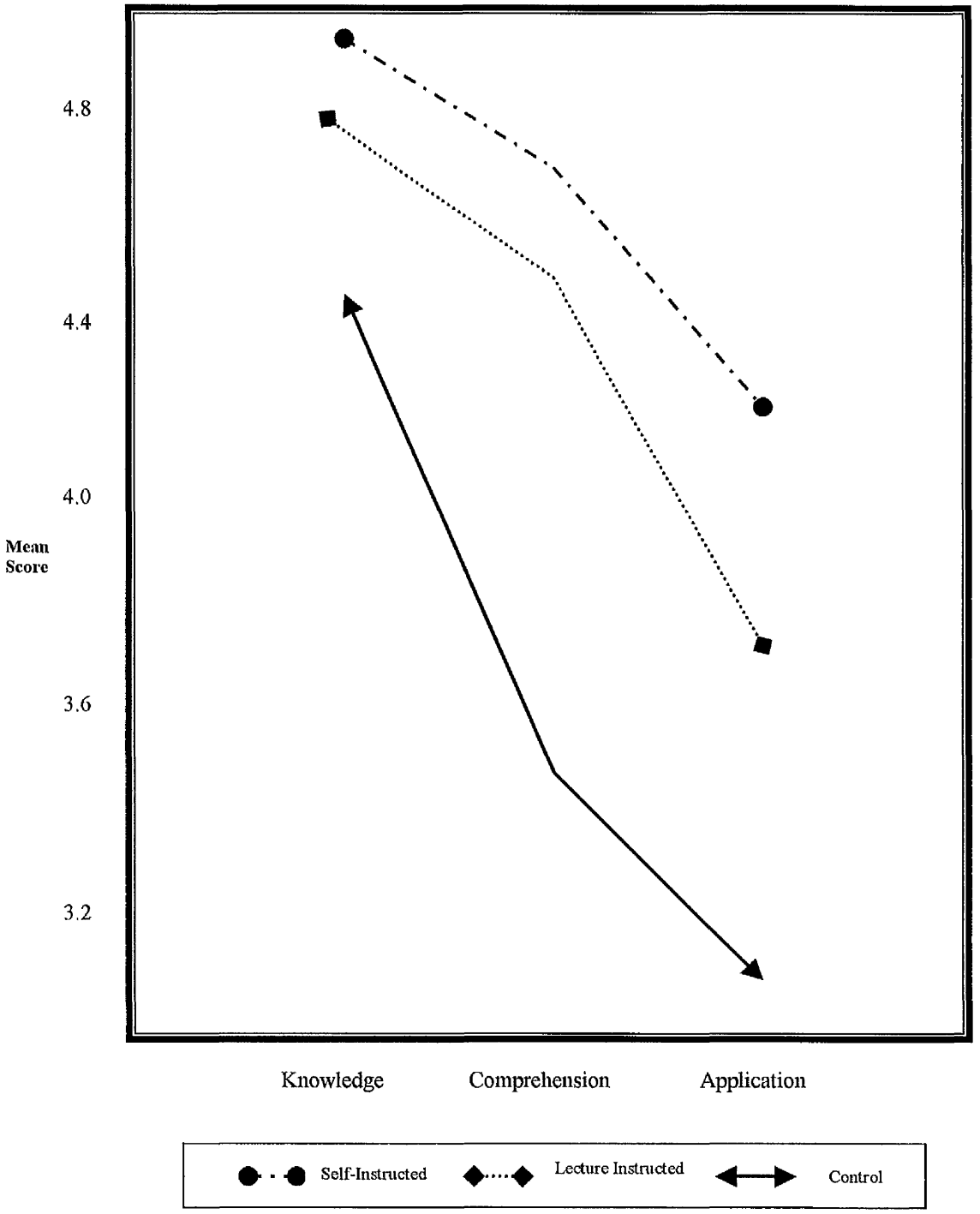
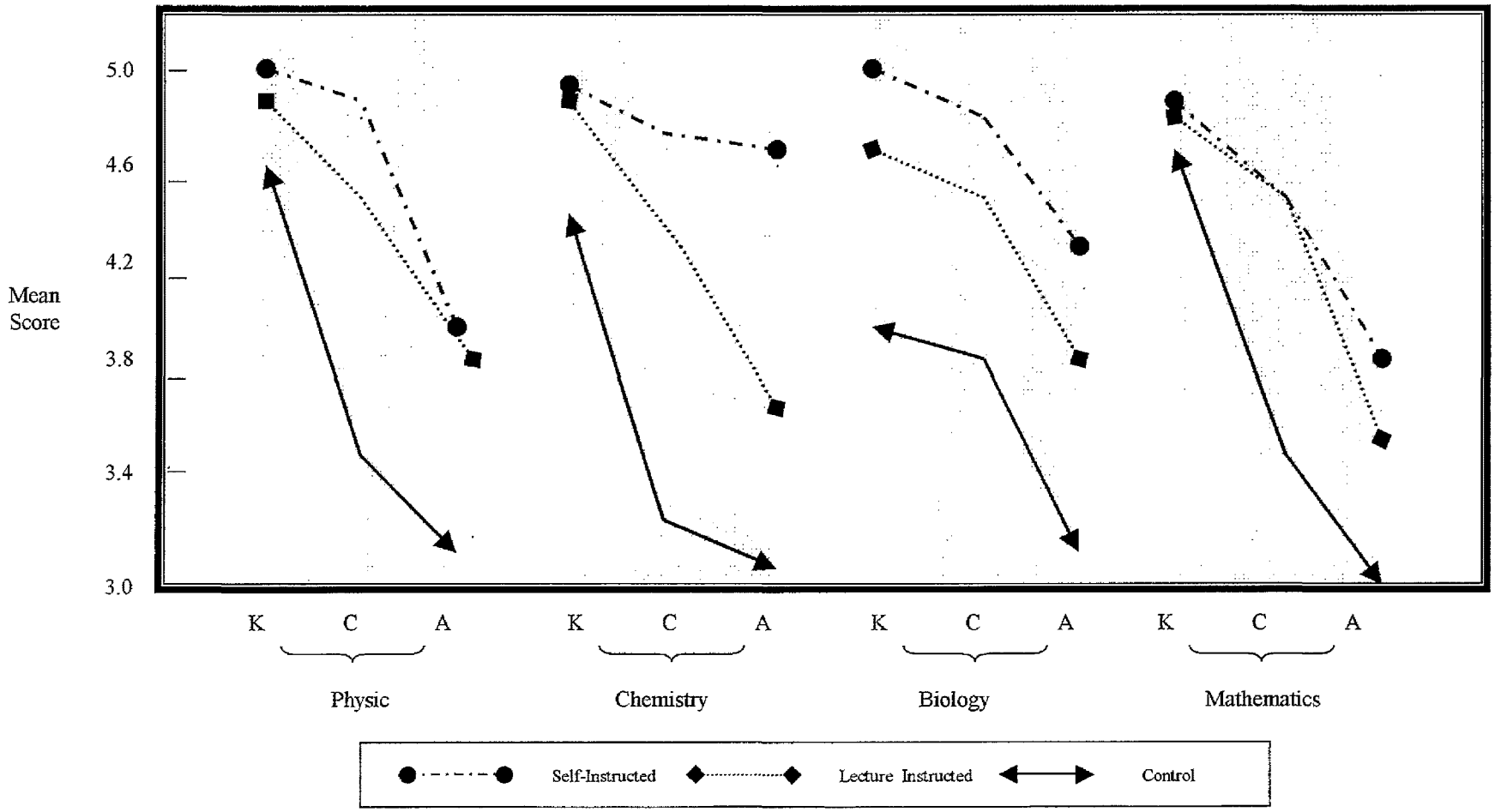


FIGURE 5.16
METHOD OF INTERVENTION STRATEGY BY MAJOR OF SPECIALISATION INTERACTION AS A FUNCTION OF EVALUATION SCORE



Following the significant interaction effect between method of intervention strategy and evaluation score as well as major of specialisation and evaluation score, a two-stage analysis of simple interaction effect was employed. First a between subject simple effect was employed (see TABLE 5.32). The main aim of this analysis is to dissect method of intervention strategy X major of specialisation interaction at every level of cognitive operation. As suggested by Howell (1997), the easiest way of testing the between subject effects is by running a separate two-way (method of intervention strategy X major of specialisation) analysis of variance at each level of cognitive operation. From the results presented in TABLE 1, 2 and 3 (APPENDIX M), there is a significant difference between method of intervention strategy (self-instructed obtained the highest mean score, followed by the lecture instructed and control group at every level of cognitive operation). However, there is no significant major of specialisation effect, nor is there a method of intervention strategy X major of specialisation interaction. From the output and the graphical illustrations of the interaction (FIGURE 5.15 and 5.16), it could also be implied that the self-instructed exceed the lecture instructed and control group by just about the same score in each level of cognitive operation.

In the second stage of simple interaction analysis, a within subject simple interaction analysis was employed (see TABLE 5.32). The main aim is to look at the simple effect of evaluation score for each method of intervention strategy separately in order to see how the score of student teachers in each method of intervention strategy changes as a function of the evaluation score. In conducting this analysis, major of specialisation is also included as an effect since this avoids the increase of the error term (Howell, 1997). As a result, three separate 4 X 3 (major of specialisation X evaluation score) repeated measures MANOVA at each method of intervention strategy are employed. The relevant analyses are presented in TABLE 4, 5 and 6 (APPENDIX M). From these results, a significant difference due to major of specialisation is only shown in the self-instructed group. However, in every method of intervention strategy significant differences in evaluation scores are demonstrated. There is no major of specialisation X evaluation interaction shown in any method of

intervention strategy. The results in the simple analysis reveal that when we average across major of specialisation, the change in the evaluation score is only shown in the self-instructed group. As detected through a follow up analysis of variance (TABLE 7, 8 and 9 (APPENDIX M)) the main effect of major of specialisation is only significant at the application level of cognitive operation. It seems that the result in the simple interaction analysis is parallel to the earlier conclusion that is drawn from the overall analysis (TABLE 5.32); viz. there is significant method by evaluation score interaction. Nevertheless, the interaction between major of specialisation and evaluation score is only significant in the self-instructed group, exclusively at the application level of cognitive operation.

5.6.6. Summary of Findings on the Evaluation Test

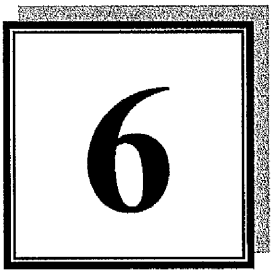
Analysis of the evaluation test revealed the dominant role played by the intervention strategy in equipping the science student teachers with sound pedagogical knowledge of how to embed critical thinking in their science instruction. The student teachers in the test group not only scored significantly higher on the total evaluation score, but also at all levels of cognitive operations (knowledge, comprehension and application). When looking at every method of intervention strategy, significant differences in terms of score also occurred (see ANOVA table, §5.6.3). Besides the effect of treatment, the correlation between the post-test scores and the evaluation score at the application level of cognitive operation in the test group (self-instructed and lecture instructed) is also significant. It could be inferred that as the student teachers progressed affectively; viz. improved their attitude or dispositions towards critical thinking, their cognitive ability (particularly at the higher level) will also be improved. Whereas at lower level of cognitive operations (knowledge and comprehension), attitude does not play a significant role in student teachers' approach to hypothetical or problem solving situations.

The analysis of the main effect presents a more accurate picture of the implications of the intervention strategy towards the student teachers' mastery of

subject knowledge. It is found that not only do the three groups score significantly differently in each level of cognitive operation, but their scoring patterns are also identical; viz. the self-instructed group scored the highest mean score, followed by the lecture instructed and the control group at all levels of cognitive operations. With respect to the major of specialisation, a significant effect is only shown in the self-instructed group, exclusively at the application level of cognitive operation. It is thus arguable that the student teachers' knowledge acquisition, particularly at the higher level of cognitive operation, can be improved by the self-instructed method of instruction. Indeed, self-instructed students' theoretical knowledge background is a guide to achievement potential.

5.7. SUMMARY OF THE FINDINGS

From a series of analyses (§5.3.to §5.6), the domination of the self-instruction as the most appropriate method in equipping the science student teachers with the pedagogical content knowledge of how to embed critical thinking in their science instruction is made clear. In terms of the student teachers' dispositions towards critical thinking, this mode of intervention strategy has successfully changed the student teachers' **T**ruth Seeking, **O**pen Mindedness, **S**ystematicity, **I**nquisitiveness and **M**aturity attributes. Nevertheless, the strong, pre-existing **A**nalyticity and Self **C**onfidence traits resist change and hence, could not be used as predictors of the overall post-test scores. Another significant finding is the relationship between the critical thinking ability and critical thinking dispositions. In terms of student teachers' mastery of the pedagogical content knowledge, again the self-instruction has been demonstrated as the most appropriate means of instruction as compared to the traditional lecturing method. The extent to which the intervention strategy manages to instill positive teaching behaviour concerning the student teachers' instruction of critical thinking will be presented in the next chapter.



TEACHERS' CLASSROOM BEHAVIOUR

6.1. INTRODUCTION

In this study, recording classroom transactions systematically means mapping the processes of classroom interactions so that the relationship between objectives and outcomes can be demonstrated. In this way hypothesised links with outcomes can be tested, and congruence between intentions and outcomes explored (Eggleston, 1980). As highlighted earlier in CHAPTER FOUR (§4.7), the observation conducted in this study is designed to record whether student teachers who had been exposed to an intervention strategy designed to encourage them to embed critical thinking in everyday science lessons, actually do so in the classroom. This is the final and vital step in any intervention strategy and one frequently overlooked. Specifically, the observation was conducted to explore the following:

- the pattern of intellectual transaction which student teachers employ with their pupils;
- the variation of the intellectual transactions with respect to the method of intervention strategy; and
- the variation in the instructional approaches which the student teachers employ to develop cognitive abilities in pupils.

In any observational studies, a good deal can be learned from qualitative data. A review of the related literature shows that a comparison between the findings of the observation studies commonly conducted by most researchers did not proceed beyond the descriptive stage (e.g. Abdullah, 1987; Muthwii, 1987; Kassim, 1989; Sharifah Nor, 1994). Thus, in accomplishing the first two aims, data gleaned from the observation was primarily treated in a qualitative and descriptive manner. The fulfilment of the final aim; viz. extraction of the instructional approaches employed by the student teachers was attained by means of factor analysis technique. This analysis was followed up by the application of the *Kruskal – Wallis Test* to detect significant differences, if any, across every factor with respect to the method of intervention strategy.

6.2. THE SCORING PROCEDURES

There is ample evidence to indicate that teacher classroom behaviour appears as a function of grade level of class, age of the teacher and the content of the subject matter (Biddle, 1967; Cohen, 1972; Dreyfus and Eggleston, 1979; Hacker, Hawkes, and Hefferman, 1979; Hacker 1984). In an attempt to homogenise the grade level and the subject matter taught, 15 student teachers from each intervention group were selected. Each student teacher was then observed for one 90-minute lesson. During the observation, no attempt was made to control the type of activity performed by the student teachers, nor were they aware of the reasons for the observation. The main concern was to observe what was going on in the classroom and to document as much of it as the structure of the STOS permits. The student teachers were informed about the observation, and the non-participant observer, who was self-trained using the STOS User's Manual (Eggleston, Galton, and Jones, 1975) arrived at a prescheduled time, and sat at the back of the room as unobtrusively as possible.

The calculation of frequencies of intellectual transactions was done by calculating the frequency of use of the categories within a lesson lasting for 90 minutes ((30 X 3) time unit) and then converting them into a percentage frequency as follows:

$$\frac{\text{Number of Time Unit in which Category Occurred}}{\text{Total Number of Time Unit}} \times \frac{100}{1}$$

6.3. THE PERCENTAGE FREQUENCY OF USE OF THE STOS CATEGORIES

6.3.1. The Overall Percentage Frequency

The percentage frequency counts of categories and subcategories per 100 time unit were tallied and aggregated for each of the student teachers and then computed as mean and median percentages as summarised in TABLE 6.1. The insertion of median values is to denote the mid-point of each category. Additionally, it has a value not shared by the mean in that it is not affected by extreme values as in this case where half of the categories are positively skewed. Minimum and maximum scores record highest and lowest frequencies obtained in every category, since, as Smith (1977) points out, this demonstrates that an adequate range of behaviour is being observed. From TABLE 6.1, it can be seen that there is a large range of values ($frequency_{Minimum}$ 0; $frequency_{Maximum}$ 90), which will maximise differences among samples especially with regard to their method of intervention strategy.

FIGURE 6.1 depicts the seven highest mean percentages (incidence per 100 time units) of the STOS category. From FIGURE 6.1, it is clear that the teacher-initiated activities are equally balanced with pupil-initiated activities. In other words, an equilibrium exists between activities devoted both to information giving and information seeking. The occurrence of the information seeking activities is reflected by the domination of pupil consultation activity or peer to peer interaction for the purpose of making inferences, formulating and testing hypotheses (d_3). Information giving is evidenced with the preponderance of the teacher's talk, which deals mostly with questions (a_1) or statements (b_1) recalling or presenting facts and principles.

TABLE 6.1

PERCENTAGE FREQUENCY OF USE OF THE STOS CATEGORIES
(incidence per 100 time sampling units)

Main Category		Incidence per 100 time sampling units (N = 44)			
		Mean	**Median**	**Minimum**	**Maximum**
Teacher's Questions	a_1	22.6	20.0	6.7	66.7
	a_2	19.9	16.7	.0	50.0
	a_3	4.9	3.3	.0	20.0
	a_4	3.5	3.3	.0	16.7
	a_5	21.5	23.3	.0	63.3
	a_6	22.0	23.3	.0	63.3
	a_7	16.7	13.3	.0	56.7
Teacher's Statements	b_1	25.9	23.3	3.3	90.0
	b_2	6.7	5.0	.0	26.7
	b_3	6.4	6.7	.0	20.0
	b_4	8.9	10.0	.0	16.7
Teacher's Directions	c_1	15.8	10.0	.0	53.3
	c_2	12.9	6.7	.0	46.7
	c_3	18.4	20.0	.0	46.7
	c_4	7.4	8.3	.0	16.7
Pupils Seek Information or Consult	d_1	15.5	13.3	.0	46.7
	d_2	15.2	10.0	.0	50.0
	d_3	32.4	36.7	.0	53.3
	d_4	7.3	6.7	.0	20.0
Pupils Refer to Teacher	e_1	22.0	20.0	.0	56.7
	e_2	13.0	10.0	.0	36.7
	e_3	21.7	25.0	.0	36.7
	e_4	7.3	6.7	.0	20.0

Values are shown to one decimal point

FIGURE 6.1

THE SEVEN HIGHEST MEAN PERCENTAGES OF THE STOS CATEGORIES

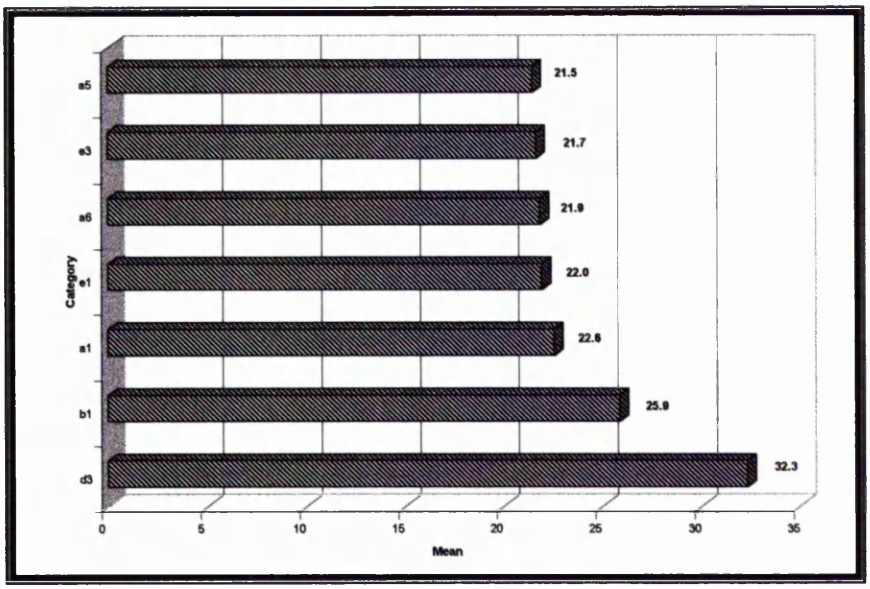
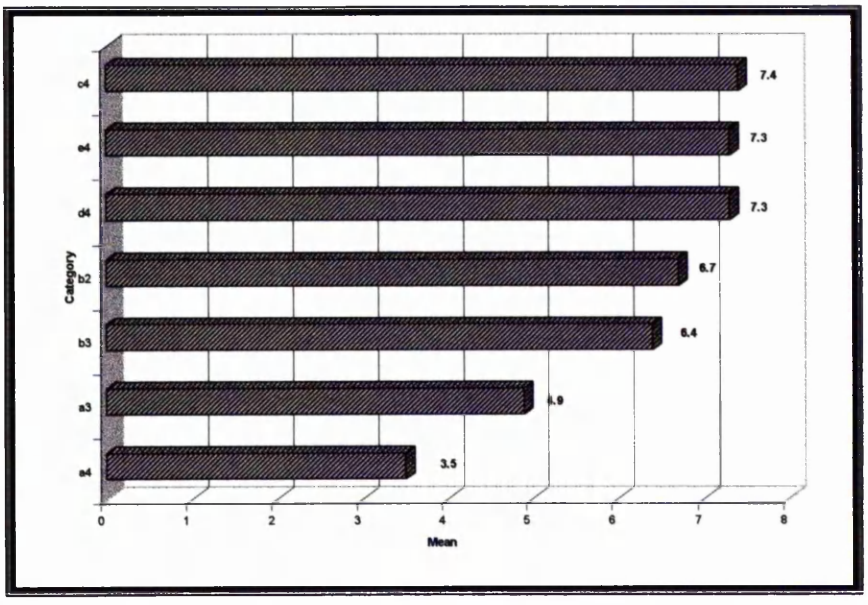


FIGURE 6.2

THE SEVEN LOWEST MEAN PERCENTAGES OF THE STOS CATEGORIES



However, the variations of teachers' questions were shown by large percentages in the categories a_5 (*questions answered by direct observation*) and a_6 (*question answered by interpretation of observed or recorded data*). Since 95% of the observations were recorded during science practical work, it is not unexpected that most of the teachers' questions were concerned with direct observation (a_5) (For example: *"What is the colour of the litmus red when it is tested on acidic substance dissolve in water?"*), as well as seeking explanation of the observed or recorded data (a_6) (For example: *"How is the molecular structure of liquid different from that of a solid?")*. Thus, it appears that teachers in guiding the pupils to interpret observational data do so by asking questions that could lead to the interpretation of those data. Pupils' resistance to these questions seems to be positive as indicated by the high percentage of category d_3 (*seeking information or consulting for the purpose of making inference, formulating or testing hypothesis*) earlier. Pupils' reliance on the teachers' guidance and explanation is evidenced with a high mean percentage representing e_1 (*referring to the teacher for the purpose of acquiring or confirming facts or principles*; 22.0%) and e_3 (*referring to the teacher for the purpose of seeking guidance when making inferences, formulating or testing hypotheses*; 21.7%).

Surprisingly, although 95% of recorded behaviour was conducted during practical work, it was very seldom that teachers asked the pupils to hypothesise their expectations of what will be observed during their practical work (a_3) (For example: *"Can you hypothesise what would be observed during neutralisation?"*) or invite them to suggest the design of the experimental procedure (a_4) (For Example: *"Can you suggest how we could perform this experiment?"*). All the remaining experimental related procedures (c_4, d_4 and e_4) are in the less frequently used categories. The lower mean percentage of category a_3 implies that teachers' questions are mainly focused on one particular possible solution (presumably the "correct" one). Very rarely were pupils given an opportunity to hypothesise or generate their own opinion. Not only that, teachers themselves seemed not to bother about making hypothetical questions or statements (a_3 and b_3). Most of the teachers' questions or statements are heavily content or fact oriented.

To summarise, the relative frequencies of the various type of information giving and information seeking behaviour summarised and illustrated in TABLE 6.1 and FIGURES 6.1 and 6.2 respectively indicate that a considerable portion of teacher behaviour consists of giving or asking for facts and definitions as compared to giving or asking for speculation or evaluation. High frequencies of inferential and speculative activities prompted by the pupils therefore could either indicate a motivation to look more profoundly at the issues or indicate pupils' difficulties in manipulating such cognitive operations. The latter explanation is the more likely since categories e_1 and e_3 (*referring to the teacher for the purpose of acquiring or confirming facts or principles and seeking guidance when making inferences, formulating or testing hypotheses*) are consistently associated with high frequencies of d_3 (*seeking information or consulting for the purpose of making inferences, formulating or testing hypotheses*).

6.3.2. The Percentage Frequency by Method of Intervention Strategy

The overview of the intellectual transactions data summarised in TABLE 6.2 indicates that student teachers in the self-instructed group exhibit the highest scores, followed by the lecture instructed group and the control group. As in the overall mean frequency (see TABLE 6.1), category d_3 (*seeking information or consulting for the purpose of making inferences, formulating or testing hypotheses*) is most frequently used by the student teachers of all groups (self-instructed = 36.0; lecture instructed = 29.8; control = 31.2). In terms of the questions posed, student teachers in the self-instructed group tend to ask questions which deal mainly with the recalling of facts and principles (a_1). Those teachers' concentration on fact giving is also reflected by a high frequency of use of category b_1 (*statement of facts and principles*) and c_1 (*directing pupils to sources of information for the purpose of acquiring or confirming facts or principles*).

TABLE 6.2

FREQUENCY OF USE OF STOS CATEGORIES BY METHOD OF INTERVENTION STRATEGY

(incidence per 100 time sampling units)

Main Category	Category	METHOD OF INTERVENTION STRATEGY											
		Self-Instructed (n=15)				Lecture Instructed (n=15)				Control (n=14)			
		Mean	Mdn	Min	Max	Mean	Mdn	Min	Max	Mean	Mdn	Min	Min
Teacher's Questions	a_1	25.6	20.0	6.7	60.0	17.7	13.3	6.7	66.7	24.5	21.7	10.0	60.0
	a_2	20.0	16.7	.0	50.0	23.1	16.7	.0	50.0	16.4	13.3	.0	50.0
	a_3	4.9	3.3	.0	20.0	4.0	3.3	.0	16.7	6.0	6.7	.0	16.7
	a_4	4.9	3.3	.0	16.7	2.2	.0	.0	10.0	3.3	1.7	.0	13.3
	a_5	18.9	20.0	.0	33.3	22.4	23.3	.0	63.3	23.3	26.7	.0	36.7
	a_6	24.4	23.3	.0	60.0	23.8	20.0	.0	63.3	17.4	20.0	.0	30.0
	a_7	18.2	13.3	.0	50.0	19.1	16.7	.0	56.7	12.6	11.7	.0	50.0
Teacher's Statements	b_1	25.3	23.3	10.0	70.0	27.3	23.3	3.3	90.0	25.0	23.3	6.7	46.7
	b_2	9.1	10.0	3.3	16.7	4.9	3.3	.0	10.0	6.2	3.3	.0	26.7
	b_3	6.9	6.7	.0	13.3	3.8	3.3	.0	10.0	8.6	8.3	.0	20.0
	b_4	10.4	13.3	.0	16.7	6.9	10.0	.0	43.3	9.5	11.7	.0	13.3
Teacher's Directions	c_1	23.1	16.7	6.7	53.3	9.3	6.7	.0	43.3	14.8	11.7	.0	40.0
	c_2	14.7	10.0	.0	46.7	15.3	13.3	.0	46.7	8.3	6.7	.0	23.3
	c_3	16.7	16.7	.0	30.0	19.1	20.0	.0	46.7	19.5	18.3	6.7	36.7
	c_4	7.1	10.0	.0	13.3	7.6	6.7	.0	16.7	7.6	8.3	.0	16.7
Pupils Seek Information or Consult	d_1	17.1	16.7	.0	46.7	13.6	10.0	.0	43.3	15.7	13.3	3.3	40.0
	d_2	18.4	13.3	3.3	50.0	16.7	13.3	3.3	43.3	10.0	6.7	.0	46.7
	d_3	36.0	40.0	.0	50.0	29.8	36.7	.0	53.3	31.2	33.3	.0	46.7
	d_4	7.1	6.7	.0	20.0	5.6	6.7	.0	13.3	9.3	10.0	.0	20.0
Pupils Refer to Teacher	e_1	25.3	23.3	10.0	50.0	18.7	16.7	.0	56.7	22.1	20.0	10.0	40.0
	e_2	15.8	10.0	3.3	36.7	10.7	10.0	.0	36.7	12.6	10.0	3.3	33.3
	e_3	25.1	30.0	.0	36.7	15.3	16.7	.0	33.3	24.8	26.7	6.7	33.3
	e_4	9.1	10.0	.0	20.0	6.0	6.7	.0	20.0	6.7	8.3	.0	16.7

Values are shown at one decimal point

It seems that this group of student teachers (self-instructed) only occasionally asks hypothetical questions (a_3) and questions which require deduction and inference from the observational data (a_7). Two main types of teachers' question could be detected; questions based on concrete, observational data (a_5 and a_6) and well-structured, problem solving questions which lead to one possible solution (a_2). It appears that the high mean percentage of d_3 and e_3, (*seeking information and referring to the teacher for the purpose of making inference, formulating or testing hypotheses*) categories is reinforced by a relatively high percentage of d_2 (*seeking information for the purpose of identifying or solving problems*). It may be that pupils' consultation is mainly for the purpose of interpreting the observed data and discussing the problem solving exercises related to the concept being investigated.

The lecture instructed group and the self-instructed group produce a similar pattern in asking hypothetical questions (a_3). However, unlike student teachers in the latter group, student teachers in the former group tend to challenge their pupils with questions demanding more than rote memory or selective recall. Not only is category a_2 (*questions which require applying facts and principles to problem solving*) frequently used, but categories a_5, (*questions on the observational data*), a_6 (*questions which require the interpretation of the observed or recorded data*), *and* a_7 (*questions which require inference to be made on the observed data*) are also among the most frequently used categories by this group of teachers. The positive correlation between d_3 and a_5, a_6 and a_7 suggests that consultation in the lecture instructed group refers to making inferences and deductions.

The questioning pattern of the control group is not dissimilar to the self-instructed group. This group of student teachers had a tendency to ask questions, which require recalling facts and principles, (a_1) and dealing with concrete observational data (a_5). The relatively high frequency of use of a_1 and a_5 is commensurate with a relatively low frequency of use of a_2 and a_6. Interestingly, although student teachers in the control group demonstrate the lowest frequency of use of a_7 (*asking inferential question*), this group of student teachers more frequently

use "hypothesise" or "speculative" questions (a_3) (mean = 6.0) relative to the self-instructed group (mean = 4.9) and lecture instructed group (mean = 4.0). The frequency of use of categories b_3 (*hypothetical or speculative statement*) and c_3 (*directing pupils to source of information for the purpose of making inference, formulating or testing hypothesis*) by this group is the highest of all the groups. This high percentage of hypothetical/speculative category is associated with a high frequency of category e_3 (*seeking teacher's guidance in making inference, formulating or testing hypotheses*). It is possible that the highest percentage of d_3 (*seeking information for the purpose of making inferences, formulating or testing hypotheses*) exhibited by the control group means that pupil consultation is not limited just to interpreting and deducing the observational data, but also encompasses a wider array of activities relating to making hypotheses or discussing speculative issues.

6.3.3. The Fraction of Interactions to the Total Recorded Behaviours

A more accurate picture emerges when one does rather more than simply comparing mean scores for categories (as in §6.3.2). The behavioural characteristics of student teachers in the different experimental groups reveal different teaching approaches being used. For each of the student teachers, a profile of the 23 STOS categories was calculated. This was achieved by taking each row and computing its total entry. This generated a profile of 23 possible behaviours for each student teacher in each experimental group. The data generated is summarised in TABLE 6.3 and illustrated in FIGURE 6.3. The profiles of the student teachers with respect to the mean probabilities of behaviour occurrence incorporated into the observational instrument are illustrated in FIGURE 6.4.

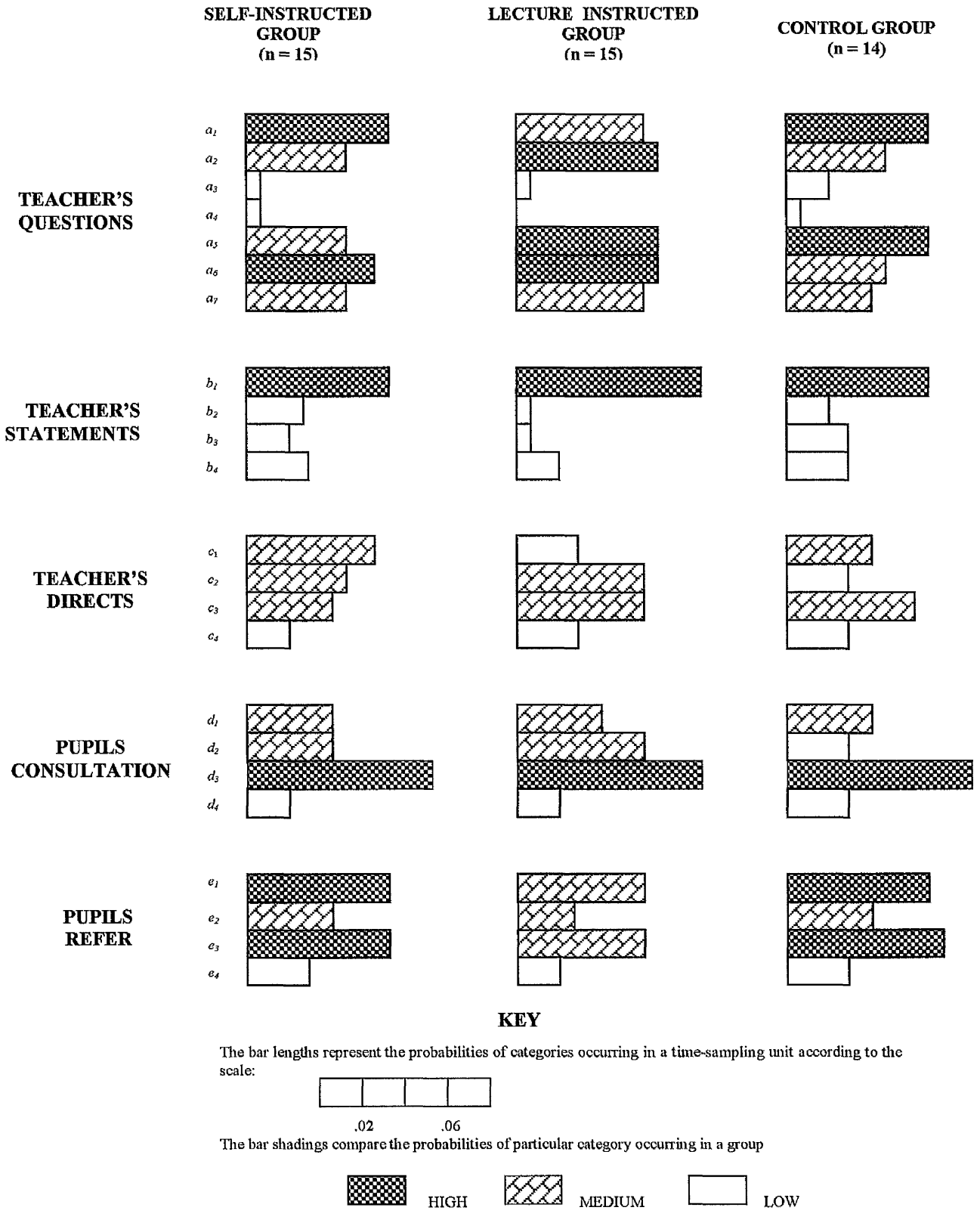
TABLE 6.3

FRACTION OF INTERACTIONS AS PROPORTION TO THE TOTAL INTERACTIONS

MAIN CATEGORY	CATEGORY	METHOD OF INTERVENTION STRATEGY		
		Self-Instructed (n = 15)	Lecture Instructed (n = 15)	Control (n = 14)
Teacher's Questions	a_1	.066	.056	.071
	a_2	.051	.072	.048
	a_3	.012	.012	.018
	a_4	.013	.007	.010
	a_5	.051	.068	.072
	a_6	.064	.070	.054
	a_7	.046	.055	.038
Total		**.303**	**.340**	**.311**
Teacher's Statements	b_1	.065	.085	.073
	b_2	.024	.014	.018
	b_3	.018	.012	.026
	b_4	.028	.022	.029
Total		**.135**	**.134**	**.146**
Teacher's Directions	c_1	.059	.029	.042
	c_2	.047	.054	.027
	c_3	.043	.058	.059
	c_4	.020	.025	.024
Total		**.159**	**.156**	**.148**
Pupils Seek Information or Consult	d_1	.045	.042	.045
	d_2	.047	.054	.027
	d_3	.094	.094	.095
	d_4	.019	.018	.029
Total		**.206**	**.210**	**.197**
Pupils Refer to Teacher	e_1	.065	.058	.065
	e_2	.040	.034	.037
	e_3	.067	.050	.075
	e_4	.025	.019	.025
Total		**.196**	**.161**	**.198**
TOTAL		**1.00**	**1.00**	**1.00**

Values are shown to three decimal places

FIGURE 6.3: THE PROFILES OF THE STUDENT TEACHERS



KEY

The bar lengths represent the probabilities of categories occurring in a time-sampling unit according to the scale:

.02 .06

The bar shadings compare the probabilities of particular category occurring in a group

From TABLE 6.3, FIGURE 6.3 and examination of the dendrogram (FIGURE 6.4), we could conclude that essentially the illustration of teacher pupil interaction is the same as that given in TABLE 6.2. However, by computing the fraction of every category in terms of the total interactions, a more accurate picture of the interaction is provided. Besides allowing differentiation of the mode of use of every category, inter-group comparisons can also be made (Carter, 1989; Dreyfus and Eggleston, 1979). In interpreting these data, it should also be borne in mind that the probability of occurrences in every category is determined by the total recorded behaviours. As highlighted in the previous section, the total recorded behaviour of student teachers in the lecture instructed group is 16% less than the self-instructed group and 4% less than the control group. For instance, higher percentage of the ratio of problem solving transactions, (a_2, b_2, c_2, d_2 and e_2) computed as a fraction of all transactions recorded in the lecture instructed group is not due to student teachers in that group engaging in such transactions more frequently (i.e. per unit time), but to the fact that such an effect may indicate that more time is spent in non-intellectual transactions or to a lack of variety in such transactions when they do occur.

TABLE 6.3 shows that a predominant feature of the observed behaviour was the preponderance of teachers' talk. The average or composite teachers' talk is about 60% of the total class time in the self-instructed group, 63% in the lecture instructed group and 61% in the control group. It is also shown that most of the teacher dominated activity is concerned with factual transactions or facts giving. Category a_1 (*questions answered by recalling facts and principles*), b_1 (*statements of facts and principles*) and c_1 (*directs pupils for the source of information for the purpose of acquiring facts or principles*) account for almost one third of the teacher initiated activity. This figure is reflected in a commensurate use of category d_1 (*pupils seeking information for the purpose of acquiring or confirming facts or principles*) and e_1 (*pupils refer to the teacher for the purpose of acquiring or confirming facts or principles*).

However, pupils' initiated activities were mostly d_3 (*seeking information for the purpose of making inferences, formulating or testing hypotheses*). In all three groups, it accounts for almost 10% of the total recorded behaviour and an average of 24% of pupils' talk. The frequency of use of e_3 (*pupils refer to the teacher for the purpose of seeking guidance when making inferences, formulating or testing hypothesis*) matches reasonably well with d_3. Together d_3 and e_3 account for almost 45% of the total pupils' initiated activity. This figure seems to inform us that most of pupils' activities are concerned with making hypotheses or inferences. Nevertheless, categories a_3, b_3 and c_3 only account for an average of 14% of the teacher initiated activity. Closer examination of these categories revealed that while student teachers in the self-instructed group only consumed 12% of their talking on these categories, student teachers in the lecture instructed group consumed 13% and the control group on the other hand consumed 31% more than the lecture instructed group (17%). The data show that the teachers seldom called the pupils to overtly make hypotheses or speculations. Although the teacher sometimes directs the pupils towards such kinds of activity (c_3), most of the time, it was the pupils who initiated the hypothetical or speculative activities.

When looking at the teachers' procedural behaviour (a_4, b_4, and c_4), only an average of 6% of the class time was spent on the experimental procedural dimension. Although 95% of the behaviours were recorded during science practical work, very seldom were pupils invited by the teachers to suggest the experimental design, and in most cases the experimental procedures were underlined by the teachers. The pupils passively responded to such procedural behaviour and in most cases references were not made to the teacher but to the textbook, where the experimental procedure was systematically and explicitly outlined. The data also suggest the lack of variability in the teacher and pupils' procedural activities. This is why category d_4 (*seeking information for the purpose of seeking guidance on experimental procedure*) and e_4 (*pupils refer to the teacher for the purpose of seeking guidance on experimental procedure*) only account for 9.9% of pupils' initiated activities in the lecture instructed group, 10.7% in the self-instructed group and 13% of the control group.

Data on the teachers' initiated activities revealed that there are mainly two types of questions, which are mostly used by teachers to invite pupils' involvement in the classroom discourse. Type One or problem solving questions deal mostly with category a_2 such as "*How many atoms are there in one molecule of methane, CH_4 and sulphuric acid, H_2SO_4 ?*" or "*Write balanced equations for the reactions of, charcoal (carbon) burning in oxygen to give carbon dioxide*". Type Two or empirical questions refer to questions that heavily rely on the interpretation of concrete, observational data (a_5, a_6 and a_7) such as "*Based on your observation, list down the properties of acids*" or "*When electroplating a brooch with copper, which one must be used as the cathode and anode*?". This also explained why most of the time, although teachers' instruction was heavily fact-oriented, when pupils refer to the teacher, they were doing it not solely for the purpose of acquiring or confirming facts and principles (e_1), but also for the reason of identifying or solving problems (e_2) and in making inferences, formulating or testing hypotheses (e_3). It seems as if the children have themselves taken responsibility for their own learning, but that this is not the aim of the teacher, it is almost by default.

6.4. THE TYPOLOGY OF TEACHING APPROACHES

The presence of a large number of categories in the STOS observational system make comparison of variables with similar sounding names a complex task. Alternatively, several reviewers (e.g. Biddle, 1967; Rosenhine, 1970b) suggested that the number of variables can be compared by using data reduction techniques. One of the most commonly used methods is factor analysis (Carter, 1989; Medley, 1958). The exploration of teaching typologies employed by the student teachers in this study started with data screening. The normality of the data was examined, the presence of the outliers detected, and the correlation and the communality of the variables were gauged (Hutcheson and Sofroniou, 1999). The data were then transformed and the new variables were mathematically extracted by using principal component analysis. Finally, in order to achieve a simpler and theoretically more meaningful factor pattern, these factors were then orthogonally rotated using the varimax rotation.

By examining the scree plot and associated eigenvalues (Cattell, 1965), three factors, which account for 70.8% of the total variance of the classroom behaviours, were extracted. The varimax rotation of the STOS categories is shown in TABLE 6.4. The magnitude of the factor loading or the correlation coefficient between the variables was then used to represent the degree of similarity between the student teachers, and the resulting analysis yielded three differentiating teaching styles which are here labelled; "*Style I*", "*Style II*" and "*Style III*". The scree plot is illustrated in FIGURE 6.4.

FIGURE 6.4

SCREE PLOT

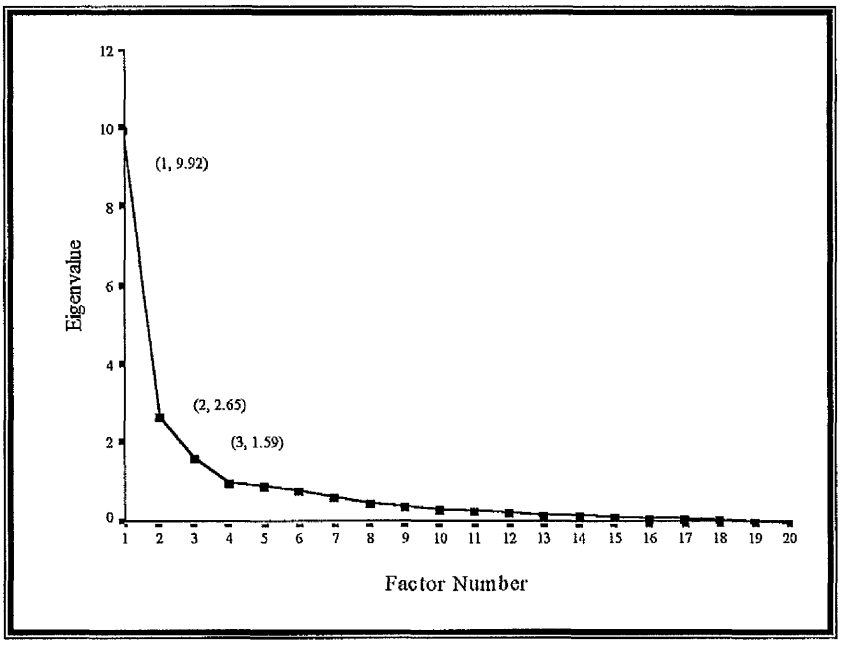


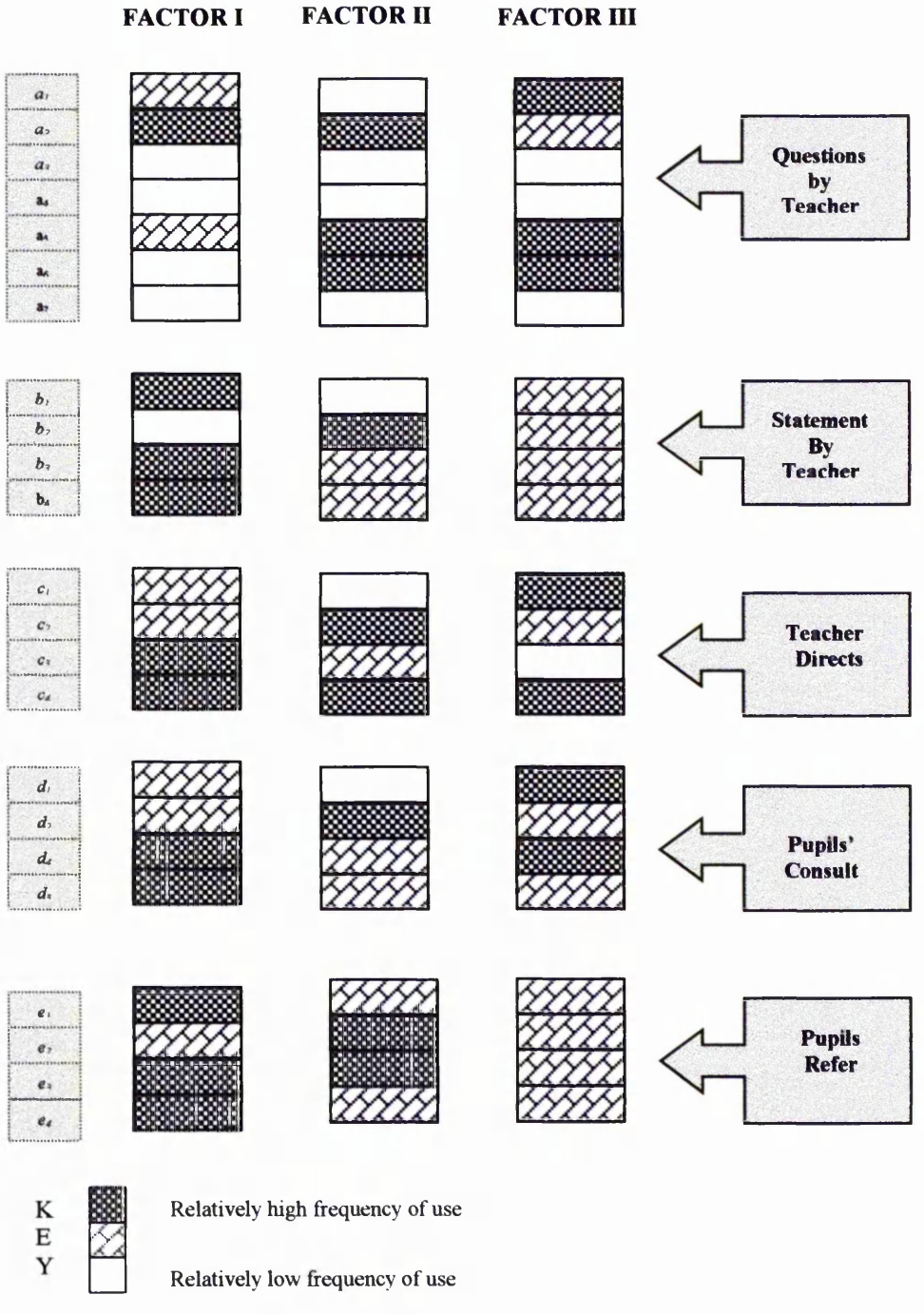
TABLE 6.4

VARIMAX ROTATED FACTOR LOADINGS FOR THE SAMPLE OF SCIENCE STUDENT TEACHERS (N = 44)

INSTRUMENT CATEGORIES	I	II	III	
TEACHER – INITIATED				
Questions answered by:				
a_1 Recalling facts and principles			.88	
a_2 Applying facts and principles to problem solving		.70		
a_3 Making hypothesis or speculation				
a_4 Designing of experimental procedure				
a_5 Direct observation			.67	
a_6 Interpretation of observed or recorded data			.75	
a_7 Making inferences from observation data				
Statement of:				
b_1 Facts and principles	.85			
b_2 Problems		.63		
b_3 Hypothesis or speculation	.57			
b_4 Experimental procedure	.65			
Directive to sources of information for the purpose of:				
c_1 Acquiring or confirming facts and principles			.85	
c_2 Identifying or solving problems		.78		
c_3Making inferences, formulating or testing hypotheses	.58			
c_4 Seeking guidance on experimental procedure	.53			
PUPIL INITIATED				
Seek information or consultation for the purpose of:				
d_1 Acquiring or confirming facts or principles			.87	
d_2 Identifying or solving problems		.78		
d_3 Making inferences, formulating or testing hypotheses	.62			
d_4 Seeking guidance on experimental procedure	.63			
Referral for the purpose of:				
e_1 Acquiring or confirming facts or principles	.76			
e_2 Seeking guidance when identifying or solving problems		.86		
e_3 Seeking guidance when making inferences, formulating or testing hypotheses	.60			
e_4 Seeking guidance on experimental procedure	.67			
% OF VARIANCE	49.6	13.3	7.9	**70.8**

FIGURE 6.5

THE CHARACTERISTICS OF THE THREE TEACHING STYLES AS EXTRACTED BY FACTOR I, II AND III



6.4.1. Factor One: *Style I*

The conspicuous feature of this pupil centred inquiry approach is mainly characterised by a relatively low frequency of teachers' talk as opposed to pupils' talk. The relatively high frequency of pupils' consultation and teacher-pupil interactions suggest a higher order of intellectualisation and a more formalised hypothetico-deductive reasoning process are being emphasised. In this approach, pupils are actively engaged in scientific process and manipulative skills. More autonomy is given to pupils to work independently with less reference to the teacher. Although the teachers seldom gave an opportunity to the pupils to suggest or construct their own hypotheses, he/she encouraged them to do so by directing them to sources of information for the purpose of making inferences, formulating or testing hypothesis. Most of the time, pupils generated hypotheses via group discussion, which was later verified by referring to the teacher. Additionally, pupils' interest on learning is reflected by a relatively high occurrences of pupils' reference to the teacher for the purpose of seeking guidance when making inferences, formulating or testing hypotheses and in confirming facts or principles being investigated. From this, it can be inferred that the high frequency of teachers' statement of facts and principles is mainly for the purpose of initiating the experiments, confirming pupils' findings and reinforcing the concepts or principles derived from the experiment.

☛ *Style I* is exemplified by one teacher teaching the concept "***Respiration in Yeast***". In the induction phase of the practical work, the teacher begins the lesson by distributing a slice of bread to all groups and asks the pupils to meticulously observe the structure of the bread. The teacher then asks question such as: *"What is the source of the bubbles of gas spreading throughout the bread?"*. Guided by the theoretical framework presented by the teacher in the previous lesson, pupils are given an opportunity to discuss among themselves and design a hypothesis. Most of the pupils suggest that during respiration by yeast, *"oxygen is used and carbon dioxide is produced"*. In order to test the hypothesis, again guided by the teacher, pupils then performed an experiment. During the experiment, pupils actively employ a trial-and-error method in attempting a solution of their problem. At this stage, guidance by the teacher helps them to determine whether the data gathered from the observation would lead to the acceptance or rejection of their prior hypothesis.

6.4.2. Factor Two: *Style II*

This is a more theoretical, teacher directed approach of emphasising science as a problem solving activity. It places emphasis on presenting scientific concepts, principles and theoretical models of problem solving. The teachers hold most of the initiative and there is a high frequency of teachers' problem statements as well as directing pupils to sources of information in seeking a solution of the problem. Frequent teachers' directive episodes are reflected in the extensive use of chalkboard, textbooks or other teaching aids during problem solving activities. In most cases, the pupils are guided towards the solution by challenging them with comprehensive arrays of questions related to the phenomena being investigated, or interpreting secondary data provided by the teachers or texts. Such an approach also necessitates "facts evaluating" in addition to the other three basis quasi-logical operations mentioned in the *Style I* (i.e. "fact stating", "fact defining" and "fact explaining").

☛ *Style II* exemplified by one teacher teaching the concept "***The Rate of Chemical Reaction***". The lesson starts by the teacher asking the following question:
"*What will you observe when you dissolve sugar in hot water?*"
and from the pupils' response, the teacher continues by asking
"*Is there any difference to the rate of reaction if you blend the sugar first?*".
During this problem posing stage, the teacher assists the pupils to put their ideas in a more researchable format so giving them a theoretical framework for investigating the phenomenon by employing an experiment. However, it seems that most of the time the teacher narrows the process by not inviting the pupils to design the experimental procedure and very rarely are they invited to make a speculative or hypothetical statement. Pupils then conduct an experiment in order to answer the question; viz. "*Does the size of the particles affect the rate of the chemical reaction*?". This question then becomes the focus of the investigation.
During the experiment, pupils articulate their thinking through communicating and interacting, receiving and processing feedback, reflecting on and evaluating solutions through peer to peer interaction. At the same time, the teacher helps the discussion by asking them to draw a graph illustrating the rate of chemical reaction between different sizes of particles as well as answering related questions written by the teacher on the chalkboard and in textbooks. The results are then shared among the pupils at the end of the lesson. The teacher closed the lesson by presenting questions for further study such as:
"*Does the presence of a catalyst facilitate the reaction?*",
"*What happens if we increase the temperature of the reaction?*"

6.4.3. Factor Three: *Style III*

The main cognitive agenda for this approach appear to be the transmission of factual information. This is a teacher-dominated approach, which is characterised by high occurrences of teachers' factual statements. Frequent pupils' factual references serve to confirm facts and lessons are concerned almost exclusively with the acquisition and regurgitation of factual information. There is a marked paucity of interactions except those of demanding recall and applying facts and principles to problem solving. Teachers' statements are mainly factual giving, and the three basic quasi-logical operations involved are "fact stating", "fact defining" and "fact explaining". There is a relatively high frequency of pupil consultation and referral for making inferences and formulating and testing hypotheses, coupled with a high frequency of pupils' factual references. All this would seem to indicate that pupils' initiated activities are mainly limited to

interpreting the concrete observational data or drawing inferences from them. Classroom practical experiments are generally employed in an illustrative role; that is they are used to confirm and verify information, rather than as a means for inquiry.

☛ *Style III* is exemplified in one of the classrooms observed when one of the teachers teaches the concept "***Order of Reactivity***". The lesson starts with the teacher making factual statements with the assistance of teaching aids, which show the electron structure of the first 20 elements in the periodic table. The teacher provokes pupils' participation by asking them questions which require recalling facts and principles of atomic number and mass number of certain atoms such as:
"*From our previous lesson, can you explain the concept atomic structure and mass number*"; and
"*From the atomic number, can you give me the electron structure of potassium and sodium*?".
Before introducing the concept of the chemical reaction, the teacher asks a simple question such as:
"*Have you seen any chemical reaction in your everyday life experiences*". There is neither guidance nor effort made by the teacher to help the pupil integrate the concept with their daily life experience. The lesson is then continued by the teacher making a factual statement of what is happening to the atoms during chemical reactions based upon the concept of electron structure by picking 6 elements from the periodic table; potassium, sodium, calcium, magnesium, zinc and iron as examples. Then the teacher gives an example of how these metals react with oxygen and water. However, the communication is only one direction; i.e. it is only the teacher who makes the statements and the pupils receive and not *vice versa*.
Then, pupils are given those six different metals and they are asked to conduct two series of experiments: Observing the reaction of these metals with oxygen as well as with water. However, before allowing pupils to start the investigation, the teacher has already suggested what should be observed by giving the pupils not only clues of what should be observed but relating the explanation with the concept of electron structure. The chemical equation representing the observations was also supplied. Presumably, pupils in conducting the experiment only do so to verify and confirm prior information given by the teacher. No speculative or hypothetical questions are provided to guide pupils' observation, and no speculative questions are given to navigate pupils' integrating of the concepts in different contexts; e.g. "*Is the pattern of reaction similar when these metals are put into a beaker containing dilute hydrochloric acid*?". And finally, the lesson ended with pupils concluding that the order of reactivity in descending order is as follows: potassium, sodium, calcium, magnesium, zinc and iron.

The typology of teaching approaches generated by the factor analysis reveals that essentially science is viewed by most of the student teachers as a means of inquiry, or as a problem solving activity, or as a process of factual and conceptual transmission. The teaching styles which correspond to *Style I, Style II,* and *Style III* are teacher as an "Enquirer", a "Problem Solver", and "Informer" or "Verifier" respectively, although reference to FIGURE 6.6 suggests that there is considerable overlap between these approaches (as is to be expected). In order to interpret further the degree of discrepancy between these approaches, for each student teacher on each intervention strategy group, a score on each of these three factors was calculated. Factor scores were computed from a direct summation of the probability data, rather than from a weighting of factor score coefficients (Carter, 1989). The probability data, which correspond to every factor as produced by the factor analysis technique, is non-parametrically tested using the *Kruskal-Wallis Test*[23]. The employment of this test is as follow-up from the factor analysis in testing whether the student teachers that are drawn from the same population implement different instructional approaches resulting from the intervention strategy they received (Howell, 1997; Wiersma, 1969).

6.4.4. Variations in the Factors across Method of Intervention Strategy

From the output table (TABLE 1, APPENDIX N), the mean ranks of the three groups across every instructional approach (teaching typology) as extracted in the factor analysis procedure are illustrated in FIGURE 1 (APPENDIX N). Teachers as the "Enquirer" are quite a dominant approach by teachers in the control group. Science is perceived mostly by the student teachers in the self-instructed group as a problem solving activity. However, both self-instructed and control groups delineate science as a sheer transmission of scientific and factual knowledge. The lecture instructed group on the other hand, places intermediate emphasis between the lowest and the highest in the "Enquirer" and "Problem

[23] As an extension of the *Mann-Whitney Test*, the *Kruskal-Wallis Test* is used when three or more independent samples are drawn from the same population but different "treatments" are used on each set.

Solver" and demonstrates the lowest mean rank of perceiving science as a sheer transmission of factual knowledge.

In verifying whether the above mentioned differences are statistically significant, attention should be shifted to the last part of the output table (TABLE 1, APPENDIX N). The p-value of .260, .229 and .625 indicate that equal mean ranks or the same frequency of instructional approach employed by the three group in the enquiry, problem solving, and knowledge transmitting mode of teaching. Thus, it can be concluded that there was no significant difference in the average numbers of instructional approaches employed by the student teachers in every teaching approach as characterised by the method of the intervention strategy.

6.5. SUMMARY OF THE FINDINGS.

In this chapter, the extent to which the intervention strategy could lead to change of teachers' teaching behaviour is explored. As shown in section §6.3.3 it was found that the predominant feature of the observed behaviour was the preponderance of teachers' talk; which consumed almost two third of the total recorded behaviour. Mainly teachers' talk was concerned with factual transactions or fact giving. Data from pupils' initiated activities seem to show that active learning is taking place albeit often by default. Nevertheless this type of communication does entail that higher order or critical thinking since performing such kinds of activity requires a substantial amount of inductive or deductive reasoning (thinking operations).

In the second part of the analysis, three main instructional strategies: "Enquirer" (Style I), "Problem Solver" (Style II) and "Verifier" (Style III) were detected. The domination of Style I and Style II reinforced the notion of scientific activity as the hypothetico-deductive method and science as a problem solving activity respectively. It could be argued that these two approaches resemble critical thinking activity as conceptualised by the philosophers and psychologists (see

§3.2.1). When these teaching approaches were compared to see whether the method of intervention strategy they received influenced the way they see science, and hence how science teaching should be, no statistical significant differences were found as the result from the *Kruskal-Wallis* analysis has shown. Results from the factor analysis reinforced the findings of the descriptive analysis. Teacher as an "Enquirer" is the most dominant teaching approach, followed by teacher as a "Problem Solver" and "Verifier".

7

DISCUSSION AND CONCLUSIONS

7.1. INTRODUCTION

Based upon the outcomes generated in the data analyses, three main issues are discussed before conclusions drawn: the student teachers' critical thinking dispositions before and after the intervention strategy which bear on the mechanism of attitude change in the affective psyche; the student teachers' critical thinking ability and the relationship between critical thinking ability and critical thinking dispositions; the acquisition of pedagogical knowledge of how to embed critical thinking in science instruction and the role of attitudes in determining student teachers' knowledge acquisition. Finally, the student teachers' actual teaching behaviour is explored in order to determine whether the intervention strategy implemented has led to changes in student teachers' actual teaching behaviour as well as their attitudes and pedagogical knowledge.

7.2. STUDENT TEACHERS' AFFECTIVE ASPECT (ATTITUDE TOWARDS CRITICAL THINKING)

7.2.1. Student Teachers' Critical Thinking Attitude Profiles before The Intervention Strategy

The California Critical Thinking Disposition Inventory (CCTDI) used in this thesis was originally developed in the United States of America (Facione *et al.*, 1995a). When a test constructed for use in one cultural setting is re-applied in another culture, the procedure involved is conceptualised by Eckenberger (1972) as an "implicit cross-cultural" research procedure. Davidson (1979) in an analysis of the literature on cross-cultural studies of beliefs and attitudes concludes that "major differences in attitude, beliefs, and values exist among cultures" (p. 153). The Malaysians attitude profile produced here can only be understood by taking cultural specifics into consideration. The results from this and other studies using the same research instruments are analysed in the light of the current scenario of Malaysian education and the status of the teaching professional in Malaysia.

In §5.3.1 and §5.3.4, prior to the intervention strategy, both the test and the control groups demonstrated a deficiency in the students' overall attitude towards critical thinking. Overall mean scores obtained by both groups ($mean_{test}$ = 261.7; $mean_{control}$ = 266.4) fell below the 280 cut-off point. Further exploration on every sub-scale revealed that both test groups (self-instructed and lecture instructed) and the control group were strong in **A**nalyticity ($mean_{test}$ = 39.3; $mean_{Control}$ = 40.1), Self **C**onfidence ($mean_{test}$ = 39.6; $mean_{Control}$ = 41.3), and **I**nquisitiveness ($mean_{test}$ = 39.9; $mean_{Control}$ = 39.9) traits. Weaknesses were shown in the **M**aturity ($mean_{test}$ = 31.5; $mean_{Control}$ = 31.3), **T**ruth Seeking ($mean_{test}$ = 36.1; $mean_{Control}$ = 36.8), **S**ystematicity ($mean_{test}$ = 36.8; $mean_{Control}$ = 38.0), and **O**pen Mindedness ($mean_{test}$ = 38.52; $mean_{Control}$ = 38.9) attributes. In most cases, higher and lower means gained in the sub-scales were also followed by a higher and lower percentage of those who scored below the cut-off point 40 (see also FIGURE 5.2).

When this attitude profile is compared to previous studies that used the same instrument, a similar trend of attitude profile is often found. For instance, Yeh (1996) found that on average Chinese respondents, like the Malaysians, were endowed with strong **I**nquisitiveness, **A**nalyticity and Self **C**onfidence critical thinking dispositions. Additionally, they also demonstrated deficiency in three major dispositional attributes; viz. **T**ruth Seeking, **S**ystematicity and **M**aturity. The author indicates that the relatively low mean score of the **T**, **S** and **M** sub-scales reveal that on average Chinese students "did not have a strong motivation in seeking the truth, asking questions, tolerating conflicting views, organising inquiry and making reflective judgement" (Yeh, 1996; p. 183). In her studies, cross cultural psychometric equivalence between Chinese and American versions of the CCTDI was also sought. It was also found that the Americans, just like their Chinese counterparts, whilst possessing strong **A**nalyticity, **I**nquisitiveness and Self **C**onfidence dispositions were weak in the motivation to seek the truth (**T**ruth Seeking). It seems this is not simply a problem attaching to Malaysian students.

Similarly, Sánchez *et al.* (1994) while investigating the correlation between personality and critical thinking dispositions of 200 undergraduates discovered that most of them scored above 40 in all the CCTDI sub-scales, with the exception of **T**ruth Seeking and **S**ystematicity. A year later, the same study was replicated with 587 new freshmen at selective, private comprehensive universities by Facione *et al.* (1995a). Once again, it was found that the most common attitudinal profiles among the samples was that students demonstrate strong CCTDI attitudinal aspects except that of **T**ruth Seeking. From the findings of these two consecutive studies, Facione *et al.* (1995a) conclude that most undergraduates did not have a strong motivation to seek the truth, nor did they feel that they approached problem solving in an organised fashion.

In Malaysia, the adaptation of the CCTDI in measuring teachers' attitudes towards critical thinking could be traced in a study conducted by Kartini (1998). Analysis of the attitude profiles of 35 History teachers (12 males and 23 females) showed that this cohort of teachers scored most highly on **I**nquisitiveness (54.3% scored over 50), followed by Self **C**onfidence (34.3% scored over 50) and **A**nalyticity (17.1% scored over 50). However, just like the science student teachers in the present study, they were deficient in **T**ruth Seeking (74.3% scored below 40), **S**ystematicity (28.6% scored below 40) and **M**aturity (25.7% scored below 40). The author argued that deficiency on the **T**ruth Seeking sub-scale would signal "a fundamental limitation of the subjects' eagerness to seek the truth in a given context and asking questions and being honest and objective in their pursuit of inquiry even if the findings did not support their self-interests or preconceived opinions" (p.271). Similarly, Bower's (1995) study on baccalaureate nursing students also found that they had a strong, positive inclination towards all the critical thinking dispositions, except **T**ruth Seeking. The lowest mean in the **S**ystematicity scale also indicates a general indifference in many students towards systematic, organised, focused, and diligent inquiry.

It could be argued that the underlying reason why the Analyticity attribute demonstrates the highest mean score as well as percentage of those who scored above the cut-off point is because it is the type of disposition that is used most in the academic domain. Analyticity is manifested by an individual's inclination to anticipate the consequences of events and ideas, and to use reason and fact-finding as main strategies to address serious problems (Facione *et al.*, 1995a; p.4-5). Analyticity is a core disposition for the inquiring mind and hence a virtue for the working professional. Such an attribute is important in many facets of student teachers' academic tasks especially in writing academic assignments, conducting science experiments, and when making speeches, particularly in debating points with other students.

Hill (1995) adds that Analyticity is the attribute which provides students with their strongest asset in academic problem solving and hence the kind of dispositional trait that colleges and universities emphasise in their programmes. This argument is supported by empirical findings from a correlational study conducted by Facione *et al* (1995a) who discovered that student performance in the English composition score is significantly correlated with the Analyticity score ($p<.003$). The significant role played by Analyticity towards students' academic competence is also reflected in an exploratory study conducted by Walsh (1996) who found that Analyticity is a common attribute possessed by most undergraduate students who were majoring in Nursing, Education, Business, English, History and Psychology regardless of gender. Being analytical disposes the person in professional practice to connect observations with his/her theoretical knowledge base. This in turn will help them to equip themselves not merely with the capability of creating an advantage, but also to anticipate events which threaten the safety or limit potential for a given client (e.g. student, patient).

Inquisitiveness on the other hand, measures intellectual curiosity and a desire for learning even if the application of knowledge is not readily apparent. It could be argued that inquisitive persons are those who are merited with intellectual courage;

an attribute which is important in keeping themselves updated with the continuous expansion of knowledge in the teaching profession. In this study, the possession of the inquisitive trait is as expected because student teachers, through their everyday life experiences, are already being able to realise that sometimes "ideas" considered dangerous or absurd are sometimes rationally justified and that conclusions or beliefs espoused by those around them are sometimes false or misleading. Additionally curiosity and a desire to know, argues Facione *et al.* (1995a), are among the defining characteristics of the liberally educated person. The democratic political environment in Malaysia provides a supportive psychological and cultural environment for the inculcation of this attribute. Not only that, but considering that the knowledge base for professional teaching competency continues to expand, coupled with the current scenario of teaching professionalism in Malaysia which is in "state of flux" (see CHAPTER TWO: §2.2), a deficit in **I**nquisitiveness would signal limitation of one's potential to develop expert knowledge and professional practical ability.

Another reason, which might result in student teachers' relatively higher scores on the **I**nquisitiveness scale can be attributed to the cross-cultural inclusion of Islamic and moral values that have been sweeping the Malaysian school system since the 1980*s*. From an Islamic perspective, the process of acquiring knowledge is a matter of religious duty. The prophet Muhammad (peace be upon him) bade his followers to *"seek knowledge from cradle to the grave"*, and to *"go in search of it as far as China"*. Not content even with that, he unreservedly made the assertion that the *"acquisition of knowledge is incumbent upon every Muslim, male and female"*. **I**nquisitiveness, as well as being an important professional trait, is therefore powerfully reinforced in such a fundamentalist Muslim environment as exists in Malaysia today.

The attribute of Self **C**onfidence according to Paul (1997), is cultivated when one performs a task by justifying why it is being performed; accept beliefs based on firm justification and not merely on the basis of authority or social pressure. 15 years of formal educational experience is long enough to cultivate beliefs in their capacity

for thinking for themselves, forming rational viewpoints, drawing reasonable conclusions and thinking coherently and logically. Decisions, even as a result of some persuasion, must be made essentially by reason.

In cross-cultural studies, most researchers "focus on cultural differences in beliefs and attitudes and look for the subset of cultures within which there is maximal similarity in terms of attitudes and beliefs and between which there is maximal heterogeneity" (Davidson, 1979; p. 153). Kline (1988), however, suggests that it is cultural differences that should receive the greater attention:

> "...the culture in which an individual develops provides his environment, and thus if the environment has any effect upon personality and its development it should show itself through differences between cultural group"
>
> (Kline, 1988; p.3-4)

Student teachers in this study, although holding strong **A**nalyticity, Self **C**onfidence and **I**nquisitiveness dispositions towards critical thinking, are relatively disinclined towards **M**aturity, **S**ystematicity, **O**pen Mindedness, and **T**ruth Seeking dispositions. The English samples (Facione *et al.*, 1995a; Yeh, 1996; Sánchez *et al.*, 1994) although demonstrating a similar pattern of attitude profile, score relatively higher in **M**aturity, **S**ystematicity, **O**pen Mindedness and **T**ruth Seeking when compared with the student teachers in the present study and the Chinese in Yeh's (1996) study. The following discussion is restricted to those attitudes in which the student teachers in this study are shown to be different from Americans.

Truth Seeking is described by Facione *et al.* (1995a) as a "courageous craving for the best of knowledge, even if such knowledge fails to support one's preconceptions or beliefs". Thus, it could be argued that the lack of such an attitude implies a lack of intellectual perseverance; viz. having a consciousness of the need to use intellectual insight in spite of difficulties, and having a firm adherence to rational principles despite the irrational opposition of others, and to assimilate in oneself the need to struggle with confusion and unsettled questions over an extended period of time to achieve deeper understanding or insight (Paul, 1997). In Malaysia, the practice of exam-oriented education and assessment, emphasises heavily the lower

levels of Bloom's Taxonomy of cognitive operations; viz. knowledge and comprehension (Kartini, 1988; Sharifah Nor, 1994). Mohd Hazim (1997) goes so far as to claim:

> "...in order to produce good examination results, to accede to the wishes of school administrators, parents..., teachers adopted the "forecasting" or "spotting of topic" approach, ...teachers only paid attention and visits to those topics expected to be examined in the examination paper"
>
> (Mohd Hazim, 1997; p. 225)

Thus, failure to emphasise the higher cognitive levels of achievement in Malaysia could be argued to relate to a population of graduates who do not possess the attribute of **T**ruth Seeking. Such assessment practice is opposite to Islamic beliefs; which perceived problem solving as a litmus test for the success or failure of Islamic development (Zubairi, 1989). The main topic of Al Quran is in fact the human mind. In particular, it deals with the question of how humans use or should use their cognition in responding to events (e.g. the alternation of the night and day) and physical entities (e.g. stars and moon) in their surroundings (Al Quran 2; 164). Thus, insofar as Malaysian Muslims are committed to the Islamic faith, their **T**ruth Seeking attitude will or should be cultivated. However, the social pressures in Malaysia today may be such as to discourage **T**ruth Seeking about Islam for fear of finding it wanting in one respect or another. Paradoxically, the very faith which in theory encourages the attitude of **T**ruth Seeking may in practice discourage it.

We now turn to the attributes of **O**pen Mindedness, **S**ystematicity and **M**aturity. It is almost a truism that the quality of cognitive processing improves with developmental maturity. The development of appropriate attitudes by beginning teachers, as Veenman (1984) suggests, is related to the theories and ideas derived from the studies of Piaget in cognitive development, of Kegan in ego development, and of Kohlberg in moral development. In general, all posit a sequence of cognitive structure, or stages which are organised in an invariant, hierarchical sequence from less complex to more complex, and which develop as a function of time (age).

Kegan's theory (Kegan, 1982; 1994) postulates that individuals undergo six stages or "order of consciousness" and each stage is determined by the individual's

level of personal knowledge about him/herself and by the conscious driving force that influences the individual's action. Student teachers in this study, like most other college students, as Kegan (1994) claims, tend to fall within the "interpersonal stage"; where individual actions in accomplishing their needs, interests and wishes are unconsciously driven and influenced by interpersonal relations. They are still not able to internally control their emotions, nor do they direct and create their own identity as can those in the 'institutional" and "inter-individual" stages. Kohlberg's theory of moral development (Colby and Kohlberg, 1987), like Kegan's, is also grounded in Piagetian and Neo-Piagetian psychology. Colby and Kohlberg (1987) describe an individual's level of moral development as circumscribed by different types of relationships one is expected to establish between self and society. Colby and Kohlberg (1987) found, and Pascarella and Terenzini (1991) confirmed, that most college students approach their moral problems by reasoning at the "conventional" level. The "postconventional" levellers already have the capacity to apply universal ethical principles.

Based on Kegan's and Kohlberg's theory of personal and moral development, it could be argued that individuals who are still in the "interpersonal" and "conventional" level, although well past a period of egocentricism, are now embedded and controlled by their sociocentricism:

> "the assumption that one's own social group is inherently and self-evidently superior to all others. When a group in society sees itself as superior, and so considers its views as correct or as the only reasonable or justifiable views, and all its actions as justified, there is a tendency to presuppose this superiority in all of its thinking and thus, to think closedmindedly"
>
> (Paul, 1997; p. 1)

In this study, student teachers' relatively lower **O**pen Mindedness score could be accounted for by arguing that they are still in what Kegan and Kohlberg postulate as the "interpersonal" and "conventional" stage of moral development. In the context of Malaysia, the sense of sociocentricity is inevitable, since Malaysia is a pluralistic and multi-racial country. Although extensive efforts have been initiated since the country gained its independence to decrease the racial sentiment among the populations (see §1.2.3; page 30), such an attitude is still firmly established in the affective psyche.

Accordingly, student teachers' lower score on the **O**pen Mindedness scale is related to their attitudes towards being organised, orderly, focused, and diligent in inquiry (**S**ystematicty). The basis of this argument is that **S**ystematicity (as shown by Sánchez (1993); see §4.2.2.2. page 138) has the strongest correlation with ego resiliency: viz, a person's ability to alter their modal perceptual and behavioural functioning to adapt to situational constraints. To put it another way, those who possess **S**ystematicity dispositions towards critical thinking are flexible and adaptable persons. Thus, when they score lower in the **O**pen Mindedness scale, their score in the **S**ystematicty scale is also low.

Student teachers' low **O**pen Mindedness and **S**ystematicity scores could be argued to be as a result of the norms and values held by their society. As the student teachers who participated in this study are approximately 75% Malays and 20% Chinese, it is reasonable to justify their attitudes by referring to the values commonly shared by both societies. Malays, just like Chinese, besides having their own deity, practice five human relationships, that is sovereign and subject, father and son, husband and wife, elder brother and younger brother, and friend and friend. Except for the last, all of these are relations of authority and obedience (Yeh, 1996). Thus, no matter what kind of conflict might develop between these dyads, culturally it is not as openly displayed between the family members as in the west. Most Chinese and Malays grow in families where children usually acquiesce to the counsel of their parents or the elder members of their extended family (one example is shown in §1.3.2; page 39). As a result, Malay and Chinese children are trained to respect and obey parents, teachers, and ageing and wise people.

Additionally, Malay and Chinese children are trained to be concerned about the value of "face" (Yeh, 1996). Frankness, abruptness, and criticism that causes humiliation are avoided in public in order to maintain harmonious interpersonal relationships. Thus, in most classroom situations, Malay children, just like their Chinese counterparts, would prefer withdrawal, silence, or waiting for cues from their teachers rather than expressing their opinions directly and, as they would

perceive it, inappropriately. This in turn, would result in less awareness of their own opinions, thought and reasoning powers and hinder the development of the attitudes of **O**pen Mindedness and **S**ystematicity. This seems to be in contrast to their western counterparts who exhibit "direct self-disclosure" in their acquisition of knowledge (Pedersen, 1977).

An understanding of the **M**aturity scale reasonably resides in Piaget's theory of cognitive development. According to Piaget (1964), when individuals reach the age 11 onwards, they are in the formal operational stage of development; a stage whereby they have the ability to compare and contrast between alternatives that exist in their mind and their abstract thought is also developing. However, more recently Shayer and Adey (1981) showed that most secondary students entering school are still at the concrete operational level, and the majority remain so even at 16+. Thus, it can be argued, when these student teachers embark on tertiary education, their formal operation stage may not yet be fully developed. Gambino (1995) even claims that anywhere from 40% to 80% of college and university students are performing at the Piagetian concrete level of cognitive operations. Therefore, since **M**aturity is correlated with the disposition to be judicious in decision making; it would be expected that their ability to think critically would also be low.

7.2.2. The CCTDI Scores According to Gender and Major of Specialisation

Exploration of the student teachers attitudinal profile across major of specialisation and gender was also conducted. It was found that there are no significant differences (§5.3.4.3–5.3.4.4) as far as gender and major of specialisation are concerned in both test and control group. Major and gender similarities in the CCTDI overall score are also reflected in most studies mentioned earlier. For instance, Kartini (1998) found no significant gender differences on the critical thinking attitudinal aspect as measured by the CCTDI. Bower (1995) found that female students scored significantly higher than their male counterparts in the **O**pen Mindedness and **M**aturity scales, but found no significant difference in the overall

CCTDI score. Similarly, findings from Facione *et al.* (1994) show that female students outscored the male in the **O**pen Mindedness and **M**aturity scales, although the reverse effect is shown in the **A**nalyticity scale (males scored higher then females). Again, no significant difference is shown in the overall CCTDI score. Similarly, Walsh (1996) found that there are significant differences across gender in the **O**pen Mindedness and **M**aturity scales. And as far as major of specialisation is concerned, there is a main effect of major in all the CCTDI sub-scales except in the **A**nalyticity and **S**ystematicity scales.

It could be argued that similar attitude profiles between male and females and among major of specialisation might be due to student teachers in this study experiencing the same educational system which instils an equal perception of their social-gender roles. Their ages are also similar suggesting that they are at a roughly equal stage of cognitive and affective development.

7.2.3. Student Teachers' Critical Thinking Attitude Profiles after the Intervention Strategy

As a result of the intervention strategy, the attitude profiles of the student teachers changed in a positive direction (see FIGURE 5.6 and FIGURE 5.7). Descriptive analysis of the differences between the pre- and post-test scores in §5.3.2 and §5.3.3. reveal differences between the mean pre- and post-test score in both test and experimental groups. Following from the differences that were detected in §5.3.2, the difference in the post-test scores between the experimental and control group was empirically tested (§5.3.4.2). It was found that significant difference existed between the test and control groups in the total post-test mean scores (see TABLE 5.10). When a comparison between the post and pre-test is made within the groups, the test group (see TABLE 5.11) show significant differences in all the CCTDI sub-scales post-test scores. However, in the control group, the only significant difference between the pre- and post-test scores is shown by the **I**nquisitiveness sub-scale (see TABLE 5.12).

To explain these trends attention is focused on section §5.3.2 and §5.3.3. It could be argued that no significant difference is shown in almost all the CCTDI sub-scales (except **I**nquisitiveness) in the control group due to the phenomenon of "diminishing return", and is particularly noticeable as the learners approach higher scores on the pre-test; viz. when a "ceiling effect" occurs. In the test group (see FIGURE 5.6 and FIGURE 5.7), the "diminishing return" is significant only in the **I**nquisitiveness scale. However, in the control group, two sub-scales seem to exhibit "diminishing return" to a much larger effect (Self **C**onfidence and **A**nalyticity).

The attitude profile depicted after the intervention strategy revealed that the stronger the pre-existing attitudes (as shown by the mean score values), the more resistant they are to change. The "diminishing return" as a result of the "ceiling effect" might explain why certain attitudes changed much more significantly than the others.

7.2.4. The Effect of the Intervention Strategy upon Student Teachers' Attitude towards Critical Thinking

In seeking the most appropriate means of delivering the pedagogical content knowledge of how to embed critical thinking in science instruction, the main effects of method of intervention strategy, test time, and sub-scales as well as any possible interaction between the three (see §5.3.4.5) were calculated. Significant main effects of method and sub-scales (see FIGURE 5.8 and FIGURE 5.9) exist. The main effect of method is limited to the self-instructed group exclusively on all the CCTDI sub-scales with the exception of **A**nalyticity and Self **C**onfidence. Resonant throughout the findings of the univariate and multivariate analyses is the change in the student teachers' attitudes demonstrated by the test group. The multivariate analysis reveals a domination of self-instructed over lecture instructed method and this discussion is therefore restricted to the self-instructed group.

Essentially, the findings from this study, like many others which involve modularised or self-instructional material, tend to produce results in favour of the self-instructional method as opposed to the traditional lecturing method. For instance, Bangert *et al.* (1983) found that in 10 out of 14 studies reviewed, student attitudes were more positive towards subject matter taught by using self-instruction. In the teacher education programme, positive attitude towards subject matter as a result of modular instruction is reflected in Akindehin's (1988) study. It was found that when the science student teachers were taught via an instructional package specifically designed to promote the understanding of the nature of science as part of their science education programme, more favourable attitudes towards science were induced.

The intervention strategy correlated positively with the lower pre-existing **T**ruth Seeking, **O**pen Mindedness, **S**ystematicity, **I**nquisitiveness and **M**aturity attitudes sub-scales. These five changeable attributes seems to be among the most important attitudes as shown by Loevinger's (1976) research on ego and moral development and have the strongest correlation with the "openness to experience" construct.

The connection between **T**ruth Seeking and moral development can be traced back to the Deweyian era, where it was claimed that **T**ruth Seeking was a moral attribute associated with critical thinking. An empirical study conducted by Facione (1990) also suggests the crucial role played by **T**ruth Seeking attitudes in predicting critical thinking ability (cited in Facione *et al.*, 1995a). With regards to the other changeable attitudes, Loevinger (1976) found that an increase in "self awareness and appreciation of multiple possibilities in situation" is crucial for ego and moral development. These dispositions could be related to the tendency to being well informed (**I**nquisitiveness), looking for alternatives and being sensitive to the feeling of others (**M**aturity), and remaining open-minded (**O**pen Mindedness). Thus, insofar as **T**ruth Seeking, **I**nquisitiveness, **O**pen Mindedness and **M**aturity attitudes are

concerned, the chances of the individuals to develop their personal and moral development as well as their critical thinking ability are high.

Additionally, as highlighted earlier in §4.2.2.2, four out of these five attitudes have been empirically shown to have a positive, significant correlation to "openness to experience" (**T**ruth Seeking (r =.27), **O**pen Mindedness (r =.33), **I**nquisitiveness (r =.37) and **M**aturity (r =.30)). Additionally, **S**ystematicity, **T**ruth Seeking and **I**nquisitiveness appear to have significant positive relationship with "ego resiliency". The importance of **T**, **O**, **S**, **I** and **M** attributes is also reflected in Yeh's (1996) study which extended that besides **A**nalyticity, training teachers for critical thinking via computer simulation must emphasise the development of "**S**ystematicity, **O**pen Mindedness and cognitive **M**aturity" (p.32).

From this brief description of the student teachers' critical thinking attitude profiles before and after the intervention strategy, it could be argued that adults possess certain firmly established attitudes formed during interactions with their psychological and cultural environment. In the case of this present study, such attitudes refer particularly to **A**nalyticity and Self **C**onfidence. The so-called pre-existing attitudes although inappropriate in a changing environment, are not easily discarded in response to a small amount of new information that is inconsistent with prior viewpoints (Rokeach, 1968).

Having concluded that self-instruction is an appropriate means of delivering the pedagogical content knowledge of how to embed critical thinking in the science instruction as far as attitude towards critical thinking is concerned, we turn the discussion to the attitude change mechanism, focussing on the attitudes that are changed as the result of the intervention strategy.

7.2.5. The Mechanism of Attitude Change

Most attitude theorists (e.g. Eagley and Chaiken, 1993; Shrigley, 1978 and Wagner and Sherwood, 1969), concur that there are at least three viable theoretical models which could be used to explain the mechanism of attitude change; i) persuasive communication (Hovland, Janis and Kelly, 1953), ii) cognitive dissonance (Festinger, 1957) and iii) functional perspective (Katz, 1967). Central to all these theoretical models is the idea that emotional and motivational forces impinge upon the cognitive system.

Pajares (1992) discusses the mechanism in the light of Piaget's (1964) model of *assimilation* and *accommodation*, and that of Posner *et al.* (1982) who claimed that attitude change, like conceptual change, is analogous to Kuhn's process of paradigm shift. In this sense, Piaget's conception of *assimilation* and *accommodation* is applied in seeking an explanation about how new phenomena or information which lead to attitude change is dealt with. *Assimilation* is a process whereby new information is incorporated into existing beliefs (or attitudes) by interpreting them in the light of knowledge already gained. Nevertheless, there are occasions where information and existing beliefs must be replaced or reorganised (*accommodation*). Although both *assimilation* and *accommodation* result in belief (schemata) changes, *accommodation* leads to more radical alteration especially when the pre-existing beliefs are deep or strong. Thus, individuals are more likely to *assimilate* new information than to *accommodate* it.

Attitudes are unlikely to be changed unless they prove unsatisfactory, and they are unlikely to prove unsatisfactory unless they are challenged and one is unable to *assimilate* them into existing beliefs. In this study, it could be argued that the intervention strategy (self-instruction) has successfully led to the *accommodation* of **T**ruth Seeking, **O**pen Mindedness, **S**ystematicity, **I**nquisitiveness and **M**aturity where new schemata have been developed. However, the intervention strategy only provides opportunities for *assimilating* pre-existing **A**nalyticity and Self **C**onfidence

schemata. Therefore, there is no attitude change here since there is no paradigm shift as far as these two attitudes are concerned.

One silver thread running through the results from the attitude profiles (before and after the intervention strategy) is that **A**nalyticity and Self **C**onfidence are stronger (or more "central", see Rokeach, 1968) attitudes, and hence more resistant to change. In contrast, the other five (**T, O, S, I, M**) are "less central" and more malleable. Being more peripheral they are more susceptible to change because they are not so strongly held. It could be argued that *accommodation* (or change) of the most central beliefs would have a "knock-on" effect on the rest of the belief system. In Kuhnian terms, a radical paradigm shift would occur. FIGURE 7.1. depicts the "affective" or "attitude psyche" and illustrates the mechanism of *assimilation* and *accommodation*.

Those attitudes scoring highest on the CCTDI scale are more firmly held therefore less susceptible to change by intervention strategies and appear nearer the centre of the "affective psyche". The significant changes to the more peripheral attitudes reflect the development of new affective schemata in a process not dissimilar to the *accommodation*. The slighter changes to the central attitudes could be thought of as a process of *assimilation*. A radical Kuhnian style paradigm shift is only likely to occur when *accommodation* takes place to the more central attitudes. The intervention strategies described here have led to changes in attitudes in certain students, but not to the extent that has seen the development of a brand new belief system. This would clearly require the use of intervention strategies more powerful than the one used here. It is difficult to suggest what these might be since we have argued that distance learning is itself a relatively powerful strategy. Perhaps in the future some form of information technology involving simulation techniques might prove successful. Even if this does not prove to be possible there is an alternative to the paradigm shift. This is the process of *attrition*. The radical altering of larger numbers of peripheral attitudes might influence the more central attitudes over time.

The change of these five attitudes is also reflected in the results of the multiple regression analysis. Identification of the most influential critical thinking dispositions was made in an effort to identify which of the pre-existing critical thinking dispositions correlate most with critical thinking dispositions as a result of the intervention strategy which encourage them to embed critical thinking in their science instruction. What emerged from the regression analysis is the correlation of the five changeable attributes (**T**, **O**, **S**, **I**, **M**) with critical thinking attitudes (post-test). Strong pre-existing **A**nalyticity and Self **C**onfidence attitudes are "common" dispositions possessed by most individuals, so the mean scores in these attitude scales could not be used as predictors of attitude change as a result of any intervention or critical thinking programmes.

To summarise, as a result of intervention strategy by means of self-instructed method, five critical thinking attitudes changed. The "changeable" or "malleable" characteristics of these five "less central" attitudes could be explained theoretically by reference to the process of *assimilation* and *accommodation* in the affective psyche, and is strengthened by the result of the multiple regression analysis. Since these attitudes are "changeable", presumably, they could be regarded as predictors of attitudes after intervention programmes and hence could serve as guidelines for educators in planning attitude development programmes.

7.3. STUDENT TEACHERS' CRITICAL THINKING ABILITY

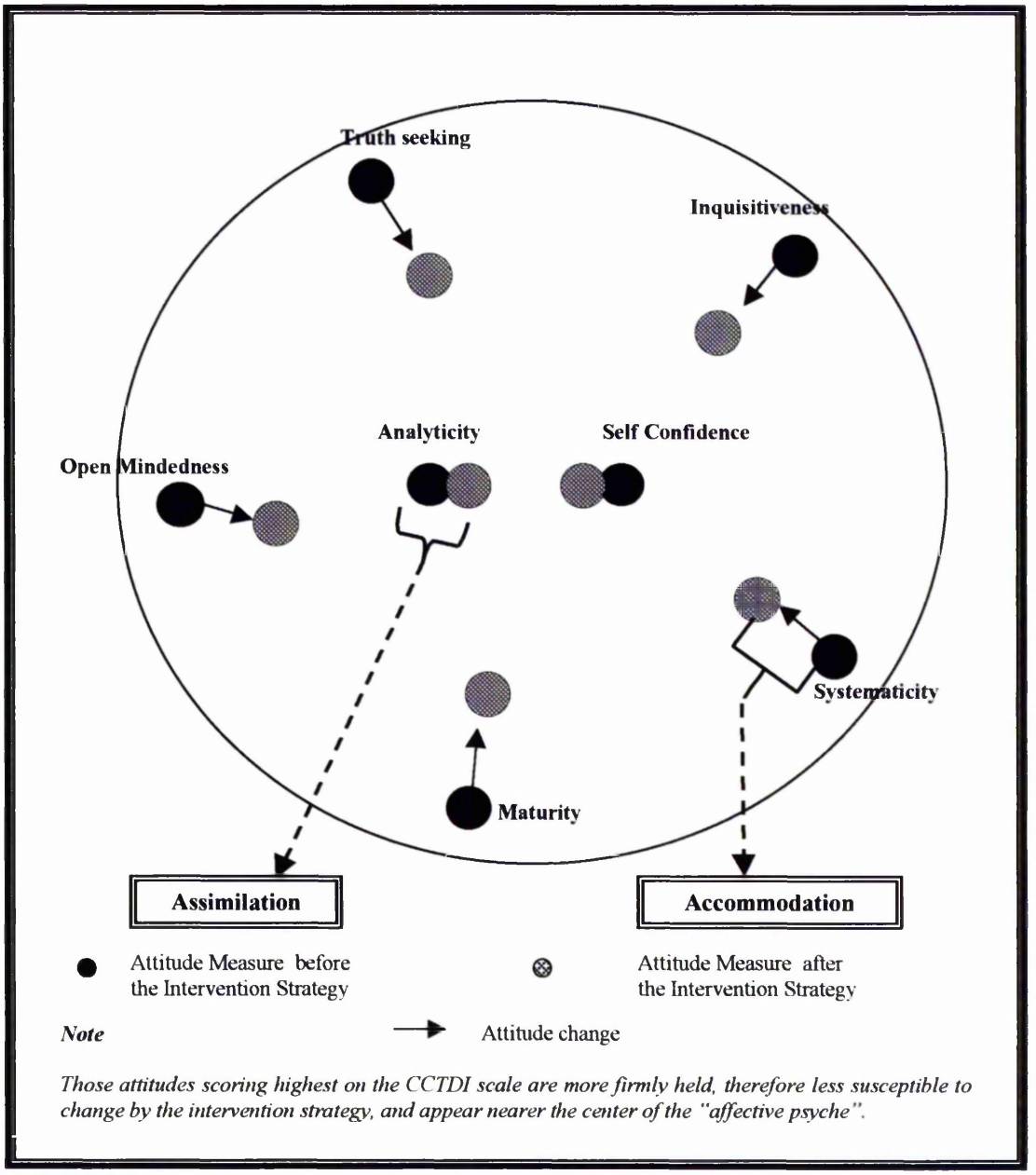
7.3.1. The Student Teachers' Ability to Think Critically

In §5.4, the student teachers' critical thinking ability was measured as a preliminary stage towards establishing the relationship between critical thinking ability and critical thinking dispositions. Additionally, data from the CCTT, Level X could also be used as an indicator of the homogeneity of the groups with regards to their ability to think critically and hence strengthening the validity of the study. The overall mean score of the CCTT, Level X is 53.27 ($mean_{self\text{-}instructed}$ = 52.20; $mean_{lecture\ instructed}$ = 51.70, and $mean_{control}$ = 53.24)(see TABLE 5.19). Both test

groups (self-instructed and lecture instructed) and the experimental group have similar means of critical thinking ability. Cognitive development is an antecedent to critical thinking ability (Gambino, 1995), and both cognitive maturity and critical thinking ability are functions of age and manifest transition from one developmental stage to the next.

FIGURE 7.1

MODEL DEPICTING THE "AFFECTIVE OR ATTITUDE PSYCHE"



Ennis, Millman and Tomko, (1985) showed freshmen students at Pacific Coast State University to have a mean score of 52.2. However, the scoring procedure employed in this thesis is different from the procedure used by Ennis, Millman and Tomko, (1985)[24]. To allow for comparison to be made, the mean score must be re-converted to its raw score ($mean_{self\text{-}instructed}$ =39; $mean_{lecture\ instructed}$ =39, and $mean_{control}$ = 40). It seems that the Malaysian student teachers' critical thinking ability is considerably lower than their American counterparts, and correlates with their lower critical thinking dispositions (pre-test). This hypothetical relationship between critical thinking ability and critical thinking dispositions was empirically tested.

7.3.2. The Relationship between Critical Thinking Ability and Critical Thinking Dispositions

TABLE 5.2 and FIGURE 5.11 and FIGURE 5.12 show a linear positive relationship between critical thinking and critical thinking ability. While acknowledging that a person who is capable of thinking critically may not be inclined to use and engage in critical thinking ability, in general terms, a positive correlation between the two is always to be expected (e.g. Bower, 1995). Success with critical thinking skills, it is then argued, reinforces disposition towards critical thinking and *vice versa*. As far back as 1933, Dewey, in *How We Think*, expressed the importance of attitudes by stating that:

> "If we were compelled to make a choice between these personal attributes and knowledge about the principles of logical reasoning together with some degree of technical skills in manipulating special logical processes, we should decide the former"
>
> (Dewey, 1933; p. 34)

As shown in CHAPTER FOUR (§4.2.1), the measurement of critical thinking ability used in this study is designed to measure four main abilities; viz. inductive inference, credibility of sources and observation, deductive inference and assumption identification (see also TABLE 4.1). The attitude measurement on the other hand measures seven attitudes. The statistically significant correlation between the two

[24] The mean score is computed by converting the raw score into percentage.

may be thought of as an *"interactionist"* or *"circular"* relationship. In addition to a one-to-one relationship between specific critical thinking skills and specific critical thinking dispositions, it is possible to postulate two other models.

Firstly, there might exist a general correlation between critical thinking skills and critical thinking dispositions; i.e. an overall disposition towards critical thinking could be conceived as a nurturing ground for a holistic development of critical thinking skills. In other words, the possession of critical thinking attitudes will induce the development of critical thinking skills and the successful use of critical thinking skills will reinforce dispositions towards critical thinking and *vice versa*. In such a case, education should be directed towards the global application of critical thinking skills, and this will result in the development of critical thinking dispositions. In this model, it would be inappropriate to concentrate on specific critical thinking skills or how to nurture one dispositional attribute in isolation from the others.

Secondly, the operative relationship between dispositions and skills might occur between specific combinations of critical thinking dispositions and specific sets of critical thinking skills. For example: **O**pen Mindedness and **A**nalyticity might lead one to openly ask interpretive and analytical questions. Cognitive **M**aturity and Self **C**onfidence might lead one towards more powerful inferences and judicious explanation. **T**ruth Seeking and **I**nquisitiveness might lead towards consistent effort in conjecturing alternatives or in honest self-reflection. In other words, skills and dispositions interact, but in interesting clusters. If this second relationship turns out to be the case, then the effort to establish exact mapping of the clustering relationship between critical thinking skills and dispositions will have significant practical implications for educators. Knowing the linkage between certain clusters of skills and dispositions can guide the development of classroom exercises and assignments. For example, exercises to strengthen skills of categorisation, analysis and interpretation might be placed together with those that require systematic and focused inquiry as well as intellectual curiosity. Exercises to develop the critical thinking

skills of evaluation and self reflection might be placed in a context whereby ethical and political debates provide ground for **O**pen Mindedness and cognitive **M**aturity.

7.4. STUDENT TEACHERS' COGNITIVE DIMENSION (PEDAGOGICAL CONTENT KNOWLEDGE) ABOUT CRITICAL THINKING)

7.4.1. Student Teachers' Acquisition of Pedagogical Content Knowledge

Just like attitude change, student teachers receiving instruction on the pedagogical content knowledge of how to embed critical thinking in their science instruction outperformed the "non treatment" (control) group at all levels of cognitive operations. The student teachers' scores are higher for knowledge acquisition than the understanding or at application level. Cross linking the results from §5.6.1, 5.6.2., 5.6.3., and §5.6.5, it can be concluded that at all levels of cognitive operations (knowledge, comprehension and application) student teachers in the self-instructed group scored significantly higher than those in the lecture instructed who scored significantly higher than those in the control group. A similar effect of modularised instruction on students' achievement has been previously shown by many studies in the past (see §4.2.4.2). In teacher education Jaus (1975), Schielack (1982), Strawitz and Malone (1987) and Akindehin (1988) have also concluded similarly.

The overview of the modularised instruction (see §4.2.4.2.) provides several explanations for these outcomes. For example, under the self-instructional condition, pupils tested themselves, checked their answers with their peers and were able to consult with the researcher if they failed to comprehend a given module. This allows self-diagnosis and feedback to correct deficiencies which in turn, improve self-motivation and self-confidence in approaching the evaluation test. The importance of intrinsic motivation in knowledge acquisition is supported by Gagné (1975) who argued that a child's ability to function independently is a direct manifestation of task motivation which in turn produced meaningful learning on the part of the learners (Ausubel, 1968). From the social cognitive perspective, it could also be argued that

the student teachers' success in the self-test increased their perceived efficacy to use self-regulated learning strategies, (which is considered as necessary for self-instruction). This in turn enhances their perceived self-efficacy for academic achievement which in turn influenced the academic goals they set for themselves and their score in the evaluation test (Zimmerman, Bandura and Martinez-Pons, 1992).

As to be expected (Johnson and Pennypacker, 1971; Born and Davis, 1974) students enrolled on the individualised instruction course devoted more time than those enrolled on the lecture sections. Time as a variable in learning has been examined in several ways by many researchers in education. For instance, Frederick and Walberg (1980) examined studies related to years of schooling, days of instruction, hours of classes, and minutes of study. Thus, it could be argued that student teachers' achievement in this present study, particularly at the application level of cognitive operation, is partly due to more time being spent on studying the materials. The amount of time spent in studying the result could also be related to the concept underpinning mastery learning. In this study, given that the student teachers' abilities are equal (see CCTT, Level X and CCTDI pre-test scores), and the content of the course is unfamiliar to the student teachers, the degree of student learning is hypothesised as a function of the ratio of time spent to the time needed (Carroll, 1963). Mathematically, the typical relationship between learning achievement (f) and time spent on learning (t) is summarised by Frederick and Walberg (1980) as follows:

$$f = a + bk + ct$$

where:

a,b, and c are constant;

k is ability; and

t is time

In the context of this study, k is shown to be equal between the treatment groups (as justified by the homogeneity of the groups as far as gender, major of specialisation, their existing attitudes toward critical thinking and critical thinking ability are

concerned), therefore differences in time spent would become a major source of individual difference.

7.4.2. The Role of Student Teachers' Attitude in Knowledge Acquisition

In §5.6.4 the relationship between student teachers' attitude and their mastery of pedagogical content knowledge was investigated. It was found that the correlation between teachers' critical thinking dispositions is only significant in the test group at the application level of cognitive operations. In the control group, no significant correlations are shown. One significant feature emerging from this finding is that student teachers' critical thinking dispositions play a pivotal role in the acquisition of higher order cognitive operations. In the test group, where significant improvement is shown in their critical thinking dispositions, the pattern of improvement is found to be correlated with their ability to perform higher order cognitive tasks.

The relationship between the student teachers' critical thinking dispositions and their score on the application level of cognitive operations has been previously shown by Hollingsworth (1989). In her explorative study of prior beliefs and cognitive change in learning, she found that student teachers that strive to confront their beliefs or attitudes developed deeper knowledge. What is consistent in Hollingsworth's (1989) finding with the finding in this study is the role of teachers' attitude as a driving factor, which motivates them to perform higher order cognitive tasks. It could also be argued that answering questions at the application level would also require retention of information before it could be meaningfully applied to the question. Reviews by Robin (1976) and Swaritz and Malone (1987) show that retention of knowledge is facilitated by using the self-instructed method which in turn may lead to the transfer of knowledge in solving questions which require application of knowledge.

From the multivariate analysis of variance §5.6.5, major of specialisation is also shown to influence student teachers' mastery at the application level of cognitive

operations (see also FIGURE 5.16). It could be that the facility for handling high level scientific concepts transfers across to an ability to apply the pedagogy of critical thinking. Although this is shown here for Chemists, it does not seem to be so for Physicists and this is more difficult to understand.

7.5. STUDENT TEACHERS' CLASSROOM BEHAVIOURS

7.5.1. Variation in the Cognitive Transaction with Respect to the Intervention Strategy

In describing the cognitive correspondence between the questions posed by the student teachers and answers elicited from the pupils, the adage "ask a higher order question, get a higher order response" appears to hold (Lamb, 1976) although in the reverse; i.e. "ask a lower order question, get a lower level response". The preponderance of teachers' talk which deals mostly with recognition or recall memory of taught material is commensurate with a relatively high frequency of pupils' talk of the same genre. The average of teachers' talk is about 60% of the total class time in the self-instructed group, 63% in the lecture instructed and 61% in the control group. However, higher order questions; viz. those which require pupils to mentally manipulate information to create an answer, or support an answer with logically reasoned evidence only account for an average of 14% of teachers' initiated activities (12% in the self-instructed group, 13% in the lecture instructed group and 17% in the control group) (see TABLE 6.3, §6.3.3).

The cognitive correspondence between the science student teachers and their pupils as revealed in this study is consistent with many researchers in the past. A review of the related literature shows teachers' tendency to emphasise facts (lower order questions) has been recognised for more than a half century. For instance, Gall (1970) in his analysis of questions posed by teachers (starting from 1912) concluded that almost 60% of teachers' questions require students to recall facts and only about 20% require them to think and left the remaining 20% for procedural activities. Studies conducted by Ajeyalemi (1981), Dillon (1982), Muthwii (1987) and Kassim

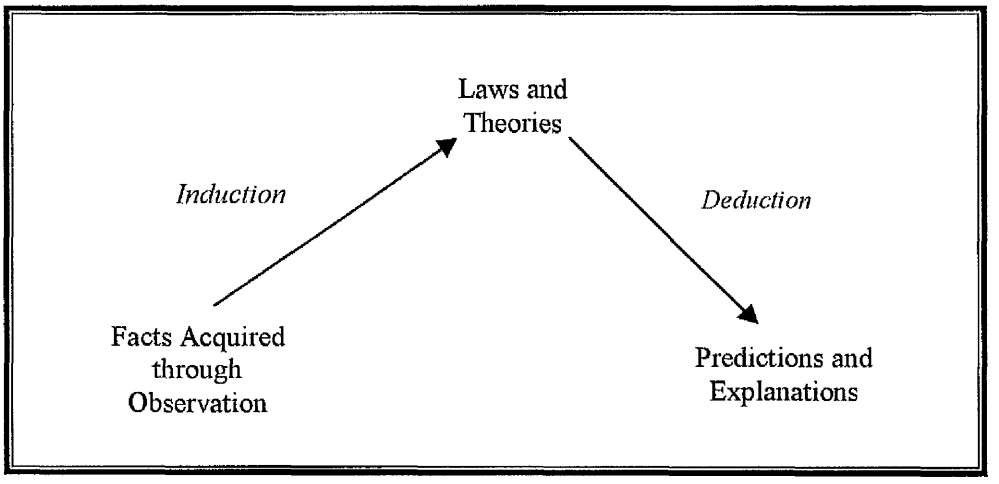
(1989) also concluded similarly. The great majority of teachers' interventions were mostly for the purpose of fact stating, explaining and opinion giving.

In terms of teachers' procedural behaviours, although 95% of the behaviours were recorded during science practical work, only 6% of class time was spent on the experimental procedural dimensions. A passive response by the pupils results in only 9.9% of pupil initiated activities in the lecture instructed group, 10.7% in the self-instructed group and 13% of the control groups being spent on experimental procedure. It could be argued that this situation is catalysed by student teachers' heavy dependence on secondary sources (science textbooks) in explaining the experimental procedures. Gall (1970) argues that higher order questions would easily come out from primary sources (e.g. newspaper editorials, observation of natural phenomena in their surroundings). Thus, teachers' heavy dependence on textbooks not only elicits lower order questions, but also shifts pupils' source of reference from teachers to the textbooks.

Interestingly, pupil initiated activities provide an opposite picture from those of teacher initiated activities. There exists a "demidissonance" (Dillon, 1982) between teachers' factual questions and pupils' initiated activities. Pupils' initiated activities however show that active learning is taking place. Relatively high frequencies of pupils' initiated activities particularly in making inferences, and in formulating and testing hypotheses, imply that it was the pupils who initiated higher order or critical thinking activities; almost by default and in spite of their teachers. Inference, which ultimately led to the conclusion, entails substantial amount of inductive or deductive reasoning to take place (see FIGURE 7.2). When information from the student teachers and pupils' initiated activities are taken together, it can be concluded that although active learning, vital for the development of critical thinking ability, is explicitly initiated by the pupils, it was teachers who actually created it. It could be argued that it was the teachers' factual statements that stimulated pupils' curiosity, which in turn inspired them to become actively involved in their learning.

FIGURE 7.2

CHAIN OF THE INDUCTIVE AND DEDUCTIVE REASONING



Dillon (1982) argues that a question requests information and a statement proffers it. Unlike the respondent to a question who is implicitly instructed to supply the information needed, the respondent to a statement is directed to accept or reject the information proffered. The functional nature of a question might circumscribe response and limit inquiry. In contrast, statements leave the probability for inquiry open. A question only directs a search for known or retrievable information, but information in a statement has a comparatively greater "surprise value". When someone is presented with information (a statement), the learner:

> "...may bring extensively to bear current knowledge and prior experience; may adduce reasons for accepting/rejecting; deduce implications; anticipate consequences, formulate opinions and conclusions; articulate refutations, explanations, and justifications; and in one way or another revise various cognitive structures related to the topic at hand"
>
> (Dillon, 1982; p. 546)

In this present study, the "demidissonance" between teachers' factual statements and pupils' responses may indeed be triggered by the statements themselves. Pupils in responding to teachers' factual statements engaged in higher level cognitive operations even when the statements themselves were framed at a low cognitive level. Thus in most cases, student teachers' type I (problem solving) and II

(empirical) questions were mostly directed to the pupils during or after the experimental procedures or any problem solving activities already taking place.

However, the role of questions as an effective means of developing critical thinking in classroom situations has been advocated by many (e.g. Costa and Lowery, 1989; Morgan and Saxton, 1991; Wilen, 1995). Teachers' questions should not be viewed as an end in themselves but a means to an end. Studies by Houston (1938) (cited in Gall, 1970) show that as the teachers increased the percentage of questions relevant to the purpose of the lessons, not only the percentage of pupils' participation increased, the percentage of questions which require pupils to manipulate facts was also increased. Not only that, there was also a reduction in a number of bothersome teaching habits such as repetition of one's questions, repetitions of pupils' answers, answering of one's own questions and interruption of student responses.

The research fails to demonstrate a positive effect of intervention strategy on actual observed classroom behaviours by the student teachers. Upon reflection, this is hardly suprising. The student teachers had not been informed that the observations were to focus on their teaching of critical thinking and problem solving, and the changes in peripheral as opposed to central attitudes to problem solving were, it has been argued, insufficient to cause a radical shift in the belief system. Although the self-instructed student teachers knew more about the teaching of thinking and problem solving, the situational context in which they might have put it to good effect was insufficiently discrete. Had the researcher informed the student teachers that it was their teaching of critical thinking and problem solving that was to form the focal point for the observation, it is possible that teaching behaviours of the three groups (self-instruction, lecture instruction, and control) would have shown more differentiation.

7.5.2. The Typology of Teaching Styles

Three teaching typologies emerged from the factor analysis (see page 266). The dominance of Style I ("Enquirer") could be accounted for by the stress placed by the Malaysian science curriculum on facilitating scientific thinking skills, which is also seen as the inculcation of good Islamic values. The training programme generally stresses that children not only *learn* science (acquire and develop factual knowledge), but also learn *about* science and require children to *do* science (see also Hodson's model of science teaching, 1985; 1987). Style II ("Problem Solver") is also represented in the factor analysis. In achieving these aims, the science education programme promotes teaching and learning strategies that involve active pupil participation. This has meant a change in the science teachers' role. Least dominant, however, is Style III ("Infomer" or "Verifier"). This is an encouraging outcome, even though there is considerable overlap (as would be expected) between the styles.

What we are unable to claim is that the intervention strategy *per se* has influenced these styles. In other words, in the context of an already powerful curriculum thrust to encourage problem solving/critical thinking the intervention strategy seems to have had little effect on teacher classroom behaviours. The reasons for this have been rehearsed elsewhere (page 296). None of this is to say that the intervention strategy has not influenced the student knowledge of an attitude towards the value of critical thinking and problem solving in the science classroom.

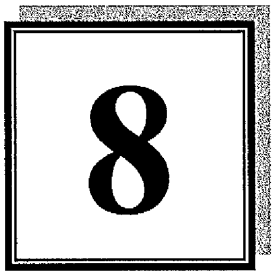
7.6. CONCLUSIONS (REVISITING THE AIMS AND OBJECTIVES ON §2.6; PAGE 76)

Based upon the findings and the discussion, it is concluded that:

- A self-instruction intervention strategy changed student teachers' attitude towards critical thinking in **T**ruth Seeking, **O**pen Mindedness, **S**ystematicity, **I**nquisitiveness and **M**aturity (see §7.2.5; page 283 - 286);

- Strong pre-existing **A**nalyticity and Self **C**onfidence traits were resistant to change regardless of type of intervention strategy (see §7.2.5; page 283-286);
- The student teachers' score in **T**ruth Seeking, **O**pen Mindedness, **S**ystematicity, **I**nquisitiveness and **M**aturity can be used as predictors of changing attitudes as a result of an intervention programme which encourages them to embed critical thinking in their science instruction (see §7.2.5; page 283 - 286);
- Gender and major of specialisation are not correlated with student teachers' attitude towards critical thinking (see §7.2.2; page 279 - 280);
- There exists a positive significant correlation between critical thinking ability and critical thinking dispositions (see §7.3.2; page 288 - 289);
- A self-instruction intervention strategy on critical thinking significantly improves student teachers' ability to apply their critical thinking skills to new situations (see §7.4.1; page 290 - 292);
- Student teachers' attitude and major of specialisation influence learning about critical thinking at the application level of cognitive operation when they were taught using the self-instructed method (see §7.4.2; page 292 - 293);
- Three teaching styles emerged from the student teachers' behaviour; Style I ("Enquirer"), Style II ("Problem Solver") and Style III ("Verifier") (see §7.5.1 - §7.5.2; page 293 - 297); and
- No observable change in student teachers' teaching behaviour occurred as a result of the intervention strategy (see §7.5.2; page 297)

Overall, the self-instruction programme resulted in improved attitudes towards critical thinking and increased knowledge of pedagogy attaching to critical thinking and improved skills of applying their knowledge of critical thinking to new situations. Despite this, no generalised change in teachers' behaviours with respect to critical thinking was observed in the classroom.



REFLECTIONS

8.1. INTRODUCTION

The research presented in this thesis is *quasi-experiemental* in design and reflects the intact nature of the sample. The intervention strategy is designed to educate science student teachers in how to embed critical thinking in their science instruction via self and lecture instruction. In gauging the effectiveness of this, the student teachers' changing attitude towards critical thinking and their mastery of the pedagogical content knowledge are measured, as is their actual teaching behaviour subsequent to the intervention strategy. Ennis's definition of critical thinking serves as the conceptual framework upon which the thesis is built and the trilogy of attitudes as having *cognitive*, *affective* and *conative* (behavioural) origins becomes the central focus of the discussion.

Inevitably, several deficiencies and weaknesses occurred. In a "reflection-*on*-action" mode (Schön, 1983), systematic and deliberate thinking back over the researcher's action is made, followed by how this might influence the findings. Subsequently, suggestions and recommendations are put forward in the context of a proposal for the effective improvement of teacher education programmes in educating the student teachers in the teaching of critical thinking.

8.2. REFLECTION

- During the analysis phase of the instructional design procedures, the characteristics of the learners, particularly their prior knowledge of the pedagogical content knowledge, were not taken into consideration. Particularising the student teachers' prior knowledge should have been done at the end of the analysis stage as this would have facilitated decisions about the starting point of the instruction. Prior knowledge is important not merely as an essential condition for learning (Gagné, 1975), but the fact that meaningful learning can only be actualised when the new information is "subsumed" or "linked" with what exists already (Ausubel, 1968).

- In the introductory phase of the intervention strategy, the student teachers were not presented with appropriate advance organisers in order to ensure the relevant anchoring of ideas as well as facilitating learning and retention (West and Fensham, 1974). This is important when the content of the instruction is unfamiliar (Ausubel, 1960).
- Many who have researched teachers' attitudes and beliefs (e.g. Pajares, 1992; Pintrich, 1990) found a strong relationship between teachers' beliefs and their planned instructional and classroom strategies. When studies fail to demonstrate a relationship between attitudes and teachers' behaviours a problem may exist in the instruments chosen. In this study, teachers' dispositions towards critical thinking are measured using the CCTDI and teachers' actual teaching behaviour is explored are means of STOS. Since STOS only concentrates on cognitive transactions perhaps it is not the best-suited instrument to be used in seeking what elements of critical thinking are being emphasised in the science classroom. Other aspects, for instance the use of wait time, concept-mapping techniques, advance organisers, thinking aloud, giving cues and prompts etc. were not taken into consideration.
- The recording of events during observation required an element of researcher judgement which might have introduced some idiosyncrasy; no "inter-observer" agreement took place. Concordance measures such as *Cohen's Kappa* (see Robson, 1992; page 223) might have been used in order to produce more reliable recording events.
- The student teachers were not informed that observation conducted by the researcher was to observe whether the teaching of critical thinking is being emphasised in their science instruction. Such information provided prior to the observation might have resulted in a different outcome.
- One of the strengths of self-instruction is that information tends to be retained over a long period of time (Strawitz and Malone, 1987). Therefore, in addition to testing the student teachers immediately subsequent to the period of intervention, student teachers should also have been tested three months

after the intervention strategy. By so doing, the value of self-instruction as opposed to lecture instruction might have been reinforced.

- The evaluation test was designed in multiple-choice format. Many assessment experts (e..g. Mehrens and Lehmann, 1984; Tuckman, 1988) claim that essay tests are a better measure of higher order thinking skills as well as allowing the student teachers to express themselves logically and coherently. Additionally in the essay response test, it is very likely the respondents reveal true feelings in essay responses rather than if they responded on an attitude scale because in the latter they might be conscious of providing a socially acceptable answer.
- Besides observing actual teaching behaviours additional measures such as open-ended interviews, responses to student teachers' dilemmas and vignettes might usefully have been conducted to provide supplemental information not only of what these student teachers were actually doing in the classroom, but what it was they were intending to do.
- Although most researchers promote individualisation as a worthwhile instructional strategy, Kapuscinki (1982) has shown that teachers' lack of knowledge of both its theoretical and practical aspects influences its effectiveness. An introductory session on the advantages of self-instruction might also have influenced the results and led to more measurable behaviour and attitude changes.
- Although this research tells us that student teachers' attitudes changed as a result of the intervention strategy, the researcher cannot identify exactly what components of the course were necessary to improve student teachers' pedagogical content knowledge and which components were important for attitude change to occur.
- Studies on the validity and the reliability of the "Bahasa Melayu" (Malay Language) version of the standardised instruments; viz. the California Critical Thinking Disposition Inventory (CCTDI) and the Cornell Critical Thinking Test, Level X used in this should be replicated by using more samples ranging from different academic backgrounds as well as cultural and racial

differences. With respect to the former, besides reliability and validity establishment as presented in CHAPTER FOUR, Confirmatory Factor Analysis (CFA) with Linear Structural RELationship (LISREL 8) might have been employed to establish the construct validity of the "Bahasa Melayu" version of the CCTDI.

8.3. IMPLICATIONS OF THE STUDY (SUGGESTIONS AND RECOMMENDATIONS)

Nevertheless, despite some weaknesses, the rigour of the findings are such as to allow several suggestions for the teaching of pedagogical content knowledge to the science student teachers in Malaysia while at the same time contributing towards their self and professional development.

- The analysis of the student teachers' attitude profiles implies that education in Malaysia rewards **A**nalyticity and not **T**ruth Seeking. Consideration should therefore be given to adjust course assignments and grading practice. Rather than exercises or exams in which students marshal arguments based on their pre-conceptions or pre-existing beliefs, it is suggested that exercises should be restructured and examinations should reward students in terms of how objectively they can present arguments (supported with evidence) against views they already hold. Grading should reinforce skills of presenting arguments which are comprehensive, and supported by a fair-minded array of accurately interpreted evidence.
- The low scores in **T**ruth Seeking present a challenge to tertiary education in general and university teacher education in particular. The vast majority of student teachers need to be induced into an academic culture which values enquiry, attends to reason, and is moved by relevant evidence. Nurturing a stronger inclination towards **T**ruth Seeking (and the other four attitudes in which the student teachers are relatively deficient) should become goals of co-curricular programmes, particularly in orientating the new students and, from student affairs as well as from the academic departments. For instance,

faculty and student development professionals might examine the extent to which the campus culture, including the student residence life programmes, support or undermine the inclination towards these five attributes (**T**ruth Seeking, **O**pen Mindedness, **S**ystematicity, Self **C**onfidence and **M**aturity)

- In order to give student teachers experience of the methodology of science and encouraging them to use teaching strategies that develop critical thinking skills, the teaching of pedagogical content knowledge of how to embed critical thinking in their science instruction should be done by integrating it with a course on the philosophy of science. By so doing, the science student teachers would acquire a more accurate picture of the methods of science as well as inserting an element of critical thinking in their instruction.
- The power of teachers' statements in initiating active and inquiry learning as revealed in this study might require student teachers, practising teachers and teacher educators to reflect on their instructional strategies and give emphasis to open statements and not merely on questions.
- The success of self-instruction in generating attitude change should be extended to the other disciplinary areas. Since critical thinking is such a vital element in an academic discipline, longitudinal investigations examining the effects of critical thinking courses by means of self-instruction on students' performance relative to students who did not take any such courses should be conducted over the four-year career of undergraduate students.
- The inter-relationship between critical thinking dispositions, skills and knowledge requires consideration if the production of critical thinkers is a prime aim.
- The three-phase design procedure (analysis, synthesis and evaluation) implemented in this study could be used as a frame of reference in instructional design not merely in the teacher education programmes but could also be applied in any instructional design at any level of schooling.

- In maximising the impact of self-instruction on pre-service as well as practising teachers' critical thinking instruction, four key factors should be incorporated into the pre-service as well as in-service training programme:
  - i) Research-based instruction concerning effective teaching of critical thinking must be employed and publicised to increase practising/pre-service teachers' professional knowledge about teaching critical thinking in different subject areas;
  - ii) As a compensatory programme, a series of guided practices and "in house training" must be implemented in order to assist pre-service and practising teachers to develop appropriate attitudes to and teaching skills in critical thinking in classroom practice;
  - iii) Consistent monitoring of teachers' teaching behaviour and immediate feedback must be given in order to increase their awareness of their teaching behaviour; and
  - iv) Collaboration through *"mentorship"* might be initiated in the teacher education programme so that an on-going monitoring of teachers' practice could be made.

8.4. A FINAL THOUGHT

The central focus of this thesis has been on how to inculcate critical thinking in Malaysian science teacher education programmes. This has been identified as an element largely missing from its curriculum. This thesis has demonstrated that there are elements, primarily attitudes and beliefs, that need to be considered before such an introduction can become fully effective. The limited studies in these areas, especially in Malaysia, make it difficult to assess to what extent the student teachers would accommodate themselves to the new subject. If the subject is as important to the nation as Vision 2020 states, and if its potential for development is as high as this thesis demonstrates, then further efforts are necessary to ensure its place in the curriculum. Embedding critical thinking in Malaysia's educational culture will probably not best be done by adding it to an already overcrowded curriculum as a

"bolt on" module as was, by necessity, done in the research reported here. Rather it needs to pervade a variety of courses in an explicit way, and become a target for assessment both theoretically and in practicum. Not to do so risks a recidivist attitude that reverts to traditional norms of Malaysian education where it is seen as simply mere knowledge for transmission.

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APPENDICES

APPENDIX A

A SAMPLE OF THE CORNELL CRITICAL THINKING TEST, LEVEL X

EXPLORING IN NICOMA

The year is 2001. It is the middle of June. Imagine yourself to be in the second group from Earth to land on the newly discovered planet Nicoma. Nothing has been heard from the first group, which landed on Nicoma two years earlier. Your group has been sent to make a report about what happened to the first group.

In this booklet, you will be told about some things learned on Nicoma by your group. Then you will be given problems that call for clear thinking. Answer these problems as if the things you are told are true.

Do not guess wildly at any answer. If you have no idea what the answer is, leave a blank. If you have a good idea, even though you are not positive, answer the problem.

The test has four parts. In the first two parts you must not go back to a problem once you have passed it.

Now wait until you are asked to begin.

SECTION I
WHAT HAPPENED TO THE FIRST GROUP?

The first job of your group is to find out what happened to the first group of explorers. Your group has landed on Nicoma and has just discovered the metal huts put up by the first group. From the outside, the huts appear to be in good condition. It is a warm day, and the sun is shining. The trees, rocks, grass, and birds make Nicoma appear like much of North Amenca.

You and the health officer are the first to arrive at the group of huts. You call out, but get no answer.

The health officer suggests, *'Maybe they're all dead."* You try to find out if he is right.

Listed below are some facts you learn. You must decide whether each fact supports the health officer's idea, or suggests that the health officer's idea is mistaken - or neither.

For each fact, mark one of the following on your answer sheet:

A. This fact **supports** the health officer's idea that everyone in the first group is dead.
B. This fact **goes against** the health officer's idea.
C. Neither: this fact does not help us decide.

Here is an example of the kind of problem in this part of the test:

1. You go into the first hut. Everything is covered by a thick layer of dust.

Is this fact **for** or **against** the health officer's idea, or **neither**? It certainly isn't enough to prove him right, but it does give some support. If a fact supports the health officer's idea, you should mark **A** on your answer sheet. Mark **A** for Number 1.

Mark your answer for this next example:

2. Other members of your group discover the first group's rocket ship nearby.

The answer is **C.** Knowing that the first group's rocket ship has been discovered doesn't help you decide one way or the other. Since this fact doesn't help you decide whether the health officer is right, C is correct.

GO ON TO THE NEXT PAGE.

Here is a list of facts. For each one mark **A, B,** or **C**. If you have no idea which to mark, leave a blank and go on to the next one. **Consider each fact in the order in which it is numbered**. Work carefully, and **do not return to a problem once you have passed it.**

Reminder - mark as follows:

A. This fact **supports** the health officer's idea that they are all dead.
B. This fact **goes against** the health officer's idea.
C. Neither: this fact does not help us decide.

3. There are ten huts. You go into the second hut and again find that everything is covered by a thick layer of dust.

4. You go into the third hut. There is no dust on the cookstove.

5. You find a can opener by the cookstove in the third hut.

6. In the third hut you find the daily record of a member of the first group. It is written by a man named John Stilltron. The date of the last entry, July 2, 1999, is one month after the arrival of the first group.

7. You find that the two beds in the third hut are covered with a thick layer of dust.

8. You read the first entry in Stilltron's record: "June 2, 1999. We arrived today after a tiring trip. We put up the huts near our landing place."

9. You read the second entry in Stilltron's record: "June 3, 1999. There is a plentiful supply of food. Ducks, squirrels, and deer are here and are easily caught."

10. You read the third entry in Stilltron's record: "June 4, 1999. The water in the nearby stream has been tested by our health official. He says it is safe to drink. We are not drinking it yet. We're going to try it with some guinea pigs we brought from earth."

11. You read the last entry in the book: "July 2,1999.1 am getting weaker and can't hold out much longer."

12. In different but shaky handwriting below the last entry, you read, "John Stilltron died the same day."

13. The health officer has now looked in each of the ten huts. He reports that there is a thick layer of dust in each of them.

14. You examine the beds in each of the first three huts. You find that in each case the blankets and sheets are stripped from the beds and folded neatly in the closets.

GO ON TO THE NEXT PAGE.

APPENDIX B

A SAMPLE OF THE CALIFORNIA CRITICAL THINKING DISPOSITION INVENTORY

CCTDI

DIRECTIONS:

1. Carefully separate the last page (ANSWER SHEET) from this test booklet.
2. Put your name on the answer sheet and on the test booklet.
3. Indicate how much you agree or disagree with each numbered statement by filling in the appropriate place on the answer sheet. Read the two examples first.

EXAMPLE A: The best things in life are free.

EXAMPLE B: I' m always doing more than my share of the work.

The answer sheet shows the responses of someone who
STRONGLY DISAGREES with EXAMPLE A
and LESS STRONGLY AGREES with EXAMPLE B.

Begin with statement number 1 and continue through number 75. Mark your response on the answer sheet in the place with the corresponding number. If you erase a response, be sure the erasure is clean.

4. After you have responded to the 75 statements, fill in the information items printed at the bottom of page 5.

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1. **Considering all the alternatives is a luxury I can't afford.**
2. **Studying new things all my life would be wonderful.**
3. **The best argument for an idea is how you feel about it at the moment.**
4. **My trouble is that I'm easilv distracted.**
5. **It's never easy to decide between competing points of view.**
6. **It bothers me when people rely on weak arguments to defend good ideas.**

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APPENDIX C

CRITICAL THINKING DISPOSITIONS AS DEFINED IN THE CCTDI

The following definitions are those supplied by the publisher, and the quotations in *italics* are items from the instrument which illustrate the definitions.

A. Truth Seeking

This is defined by the CCTDI instrument as the "disposition of being eager to seek the truth, courageous about asking questions, and honest and objective about pursuing inquiry even if the findings do not support one's self interests or one's preconceived opinions". Truth-seekers are characterised by a willingness to reconsider and revise views where reflection suggests that such change is warranted, and a demonstrated reasonableness in selecting and applying criteria appropriate to situations, together with a flexibility in considering alternatives and opinions.

People positively disposed towards "truth seeking" would generally disagree when prompted with such items as:

- *"Everyone always argues from their own self-interest, including me";*
- *"If there are four reasons in favour and one against, I'll go with the four";*
- *"To get people to agree with me I'd give any reason that worked".*

B. Open Mindedness

This is defined by the CCTDI instrument as the "disposition of being tolerant of divergent views and sensitive to the possibility of one's own bias". Regarded as possessing divergent worldviews, the open-minded person is not only willing to understand the opinions of others but also to respect the rights of others to hold differing opinions. An open-minded person will generally be expected to disagree with the items:

- *"Open-mindedness has limits when it comes to right and wrong";*

In contrast, the typical person inclined towards open-mindedness could be predicted in general to agree with:

- *"It's important to me to understand what other people think about things";*
- *"It concerns me that I might have biases of which I'm not aware"*

C. Analyticity

This is defined as the disposition of "prizing the application of reasoning and the use of evidence to resolve problems, anticipating potential conceptual or practical difficulties, and consistently being alert to the need to intervene". An analytical individual is someone who has a strong tendency to anticipate the consequences of events and ideas, and to use reason and fact-finding as main strategies to address serious problems.

People with a positive inclination towards analyticity will generally disagree with:

- *"I pretend to be logical, but I'm not";*
- *"There is no way to know whether one solution is better than another"*

But it could be predicted that they would tend to agree with:

- *"It bothers me when people rely on weak arguments to defend good ideas";*
- *"People need reasons if they are going to disagree with another's opinion".*

D. Systematicity

This is defined as the disposition towards organised, orderly, focused and diligent inquiry. People highly organised in approaching problem solving and decision-making situations will agree with:

- *"I always focus the question before I attempt to answer it".*

and will typically disagree with:

- *"My opinion about controversial topics depends a lot on who I talked to last";*
- *"People say I rush into decisions too quickly".*

E. Self Confidence

This is defined as the disposition of trusting one's own reasoning processes. Having such a characteristic will allow one to trust the soundness of one's own reasoned judgements and to lead others in the rational resolution of problems. Those who display confidence in their reasoning would be expected to agree with:

- *"Tests that require thinking, not just memorisation, are better for me";*
- *"I take pride in my ability to understand the opinions of others".*

Self-confident persons not merely trust themselves to make good judgements, but also believe that others trust them as well, since they believe others look upon them to resolve problems, decide what to do, and bring reasonable closure to inquiry. To simplify, the critical thinking self-confidence dimension implies total confidence in one's own ability to reason.

F. Inquisitiveness

This sub-scale measures one's intellectual curiosity and one's desire for learning even when the application of knowledge is not readily apparent. The inquisitive person is one who values being well informed, is always curious and wants to know how things work, and values learning even if the immediate payoff is not directly evident. In general, an inquisitive person can be predicted to agree with:

- *"No matter what the topic, I'm eager to know more about it";*
- *"Learning everything you can, you never know when it could come in handy";*
- *"Studying new things all my life would be wonderful".*

and those disinclined to be inquisitive might say that:

- *"Most college courses are uninteresting and not worth taking"*

G. Maturity

This is defined as the disposition to be judicious in decision making. The critical thinking mature person can be characterised as someone who is determined to approach problems, inquiry, and decision making with a sense that some problems are necessarily ill-structured, some situations admit of more than one plausible option, and often judgements must be made based on a context and evidence which precludes certainty. Maturity in critical thinking is also a hallmark of cognitive maturity and is recognisable, as a person who is not only able to live with ambiguity, but on occasion prefers ambiguity in preference to premature decision. Those who is immature in critical thinking will tend to agree with:

- *"The best argument for an idea is how you feel about it at the moment";*
- *"Things are as they appear to be"; and*
- *"The best way to solve problems is to ask someone else for the answers".*

APPENDIX D

THE DEFINITION OF KNOWLEDGE, COMPREHENSION AND APPLICATION

Knowledge: Recall or recognition in an appropriate context of material whether it be specific facts, universal principles, methods, process pattern, structures, or settings. Little is required besides bringing to mind the appropriate material. The knowledge cognitive operation is reflected in answering the following question:

*Which one of the following structures of the ear helps to maintain balance?**

a.	*eardrum*	*c.*	*semicircular canals*
b.	*oval window*	*d.*	*cochlea*

Comprehension: This is the lowest level of what is commonly called "understanding" and requires that the individual be able to paraphrase knowledge accurately, to explain or summarise it in its own words, or to show logical extensions in terms of implication or corollaries. Example of a question which require this level of cognitive operation is as follows:

*A scientist cultivated a large colony of disease-producing bacteria. From them, he extracted bacteria-free material referred to as substance X. A large dose of substance X was then injected into each animal of group A. These animals promptly developed some of the symptoms normally produced by infection by the bacteria in question. Then, into each animal of group B, the scientist made a series of injection of small doses of substance X. Animals in the third group, C, received no injections. Three weeks after these series of injections, and continuing for two years thereafter, group B could be made to develop the disease by injecting them with several thousand times the number of bacteria that was fatal to group C. Substance X acted upon the animals of group A as if it were a***:

a. *poison*

b. *destroyer of poison*

c. *stimulator of destroyer of poison*

---

* Adapted form Thorndike, R.L. and Hagen, E.P (1977), *Measurement and Evaluation in Psychology and Education.* New York: John Wiley and Sons.

**Adapted from Bloom., B.S. (1956), *Taxonomy of Educational Objectives.* New York: David McKay Co.

With reference to its effect upon the animals of group B, small doses of substance X appeared to act as:

a. *a means of counteracting the effects of the disease - producing bacteria*

b. *a means of stimulating the production of the bacteria or of their poisonous products*

c. *if it were a poisonous product of the bacteria*

Application: The ability to select a given abstraction (idea, rule of procedure, or generalised method) appropriates for a new situation and to correctly apply it. For example, application level of cognitive operation is required in answering the following question:

*The length of a rectangular lot exceeds its breadth by 20 yards. If each dimension is increased by 20 yards the area of the lot will be doubled. Find the shorter dimension of the original lot***

a. *20*

b. *30*

c. *35*

d. *40*

e. *none of above*

APPENDIX E

THE EVALUATION TEST

EVALUATION TEST

Matric No: ..... **Group: .....**

1. What characteristics are usually included in a definition of critical thinking?

A. Problem solving
B. Logical reasoning
C. Knowledge base
D. All of the above

2. What is true concerning the definition of critical thinking?

A. Words as diverse as lifelong learning, creativity, and decision making may be used to define critical thinking
B. Problem solving most clearly and completely defines critical thinking
C. Testing, analysis and evaluation are the most important aspects of a definition of critical thinking
D. Any definition of critical thinking should include the prerequisite knowledge base

3. The conceptual framework of the thinking enterprise will include:

A. Operations (skills), Knowledge and Dispositions
B. Operations (skills) and Knowledge
C. Knowledge and Dispositions
D. Operations (skills) and Dispositions

4. Which of the following list would **NOT** be considered a characteristic of a critical thinker?

A. Open Mindedness
B. Analyticity
C. Self Confidence
D. Honesty

continue overleaf

5. How can critical thinking best be taught in an educational programme?

A. Only as separate courses, not as part of a curriculum
B. All adult possess critical thinking skills, but these skills may be enhanced if taught in a variety of courses
C. Critical thinking should be taught primarily as part of on the job training and not in undergraduate programmes
D. Courses in critical thinking are best taught in in-service or continuing education settings

6. What is probably the most important function of teachers who are responsible for nurturing critical thinking skills and dispositions?

A. Act as a role model by demonstrating critical thinking skills
B. Teach critical thinking in a step-by-step approach
C. Assist primarily in the hypothesis generation stage especially during practical work sessions
D. Provide children with learning materials to enable them to perform critical thinking

7. Which of the following is a good method for teaching critical thinking skills?

A. Role play and simulation
B. Lecture
C. Memorisation of procedures
D. Study of textbooks and notes

8. What are the characteristics of problem based learning that make this it suitable for teaching critical thinking skills?

A. Student-centred instruction
B. Instructor acts primarily as a tutor or facilitator
C. Children have some control over direction, speed and depth of instruction
D. All of the above

continue overleaf

9. The teacher's role in promoting critical thinking skills is crucial. Some ways by which a teacher can encourage critical thinking skills are listed below **EXCEPT**:

A. Use warm up activities before each lesson such as mental exercises, brainstorming, or predicting
B. Use the variety of questions to stimulate various levels of thinking, from knowledge and comprehensive inquiries to higher order thinking
C. The provision of "wait time" or "think time" averaging three to five minutes following the presentation of questions
D. Changing the physical setting of the classroom by arranging chairs and desks in a variety of configuration

10. Which of the following is **TRUE** concerning the measurement of critical thinking?

A. Critical thinking can always be measured by using a practical exam
B. Many good tests are currently available for measuring critical thinking
C. Any critical thinking test should always be comprehensive
D. Measurement of critical thinking should be related to the circumstances and the individual being measured

11. A laboratory technician is working alone at night in a small rural hospital. Suddenly several tests, requests and specimens are simultaneously received in the laboratory. The phone rings and several doctors and nurses begin to complain that the tests are not being performed in a timely manner. One particular physician is very insistent that his patient's tests are performed immediately. The laboratory technician knows that other test requests are more urgent. What step of critical thinking will best help her in this situation?

A. Truth Seeking
B. Self Confidence
C. Maturity
D. Systematicity

12. For the situation in #11, what critical thinking skills the laboratory technician to help her determine what tests to perform first will use?

A. Analiticity
B. Maturity
C. Self Confidence
D. Inquisitiveness

continue overleaf

13. A bank manager decided to administer a critical thinking test to all new employees during the first six months of the employment. Which of the following aspects of testing would be **MOST** important for the manager to consider?

A. Who administers and scores the test
B. Relationship of questions to workplace skills
C. What time of day the test is taken
D. The length of the test

14. In order to determine the cause of the disease Y, one thousand people with the disease are examine. **ALL** had bacteria T in their lungs. The conclusion reached was a bacterium T is the cause of the disease. Which of the following can BEST be said about the above?

A. The conclusion is false because the data do not support it
B. The conclusion does not deal with the problem
C. The conclusion is a good one because the data support it
D. No conclusion should be made until people without the disease are examined

continue overleaf

15. The table below gives details of elements, which are placed in order. "Atomic weight" is placed in ascending order whereas "melting point" is arranged is descending order.

ELEMENT	ATOMIC WEIGHT	MELTING POINT/^{O}C
I	7	181
II	23	98
III		
IV	85	39
V		

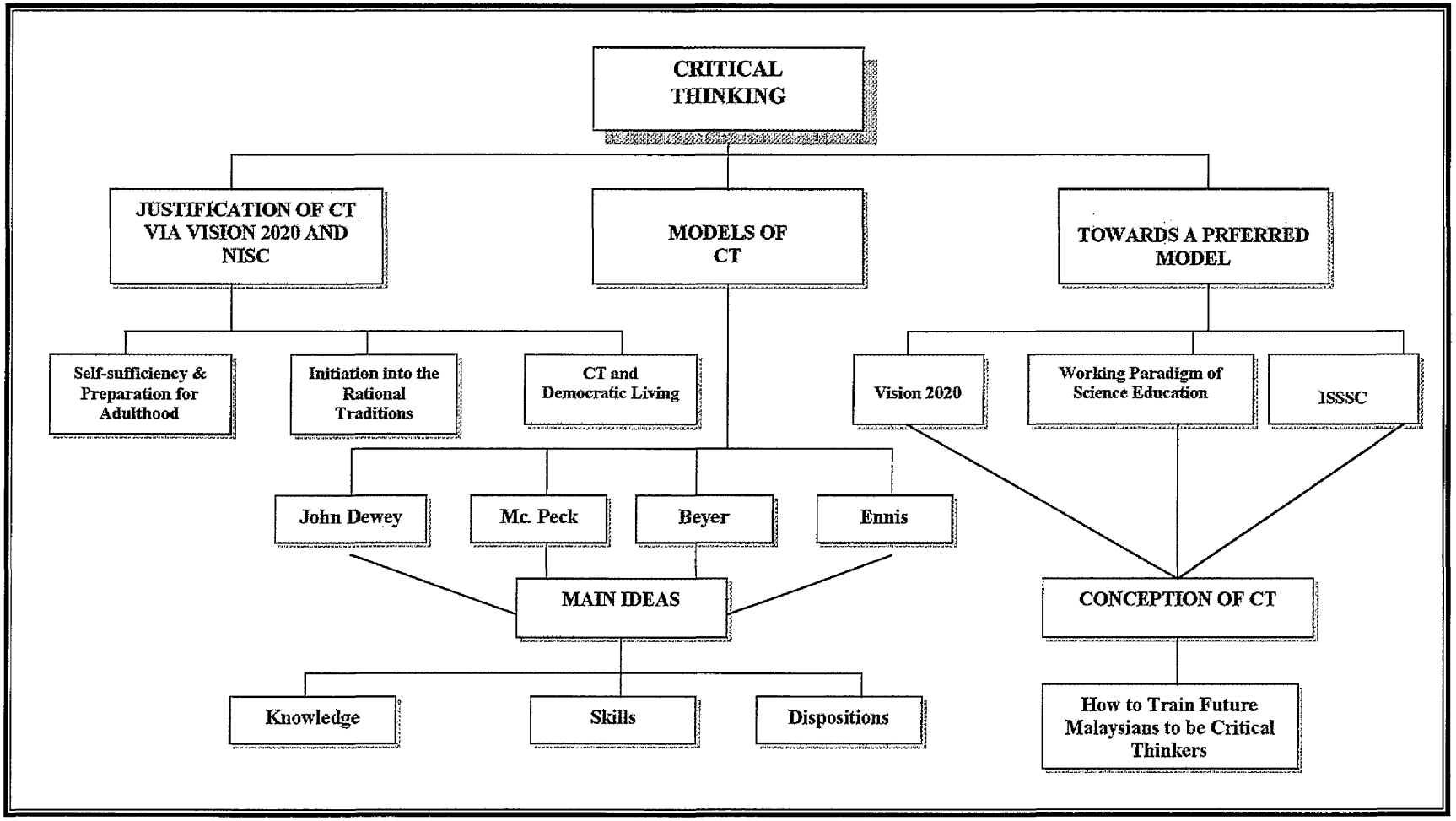
Which prediction is **MOST UNLIKELY** to be correct?

A. Atomic weight of V will be between 70 and 80
B. Melting point of III will be between 40 and 90
C. Melting point of V will be below 30
D. Atomic weight of III will be between 30 and 80.

APPENDIX F

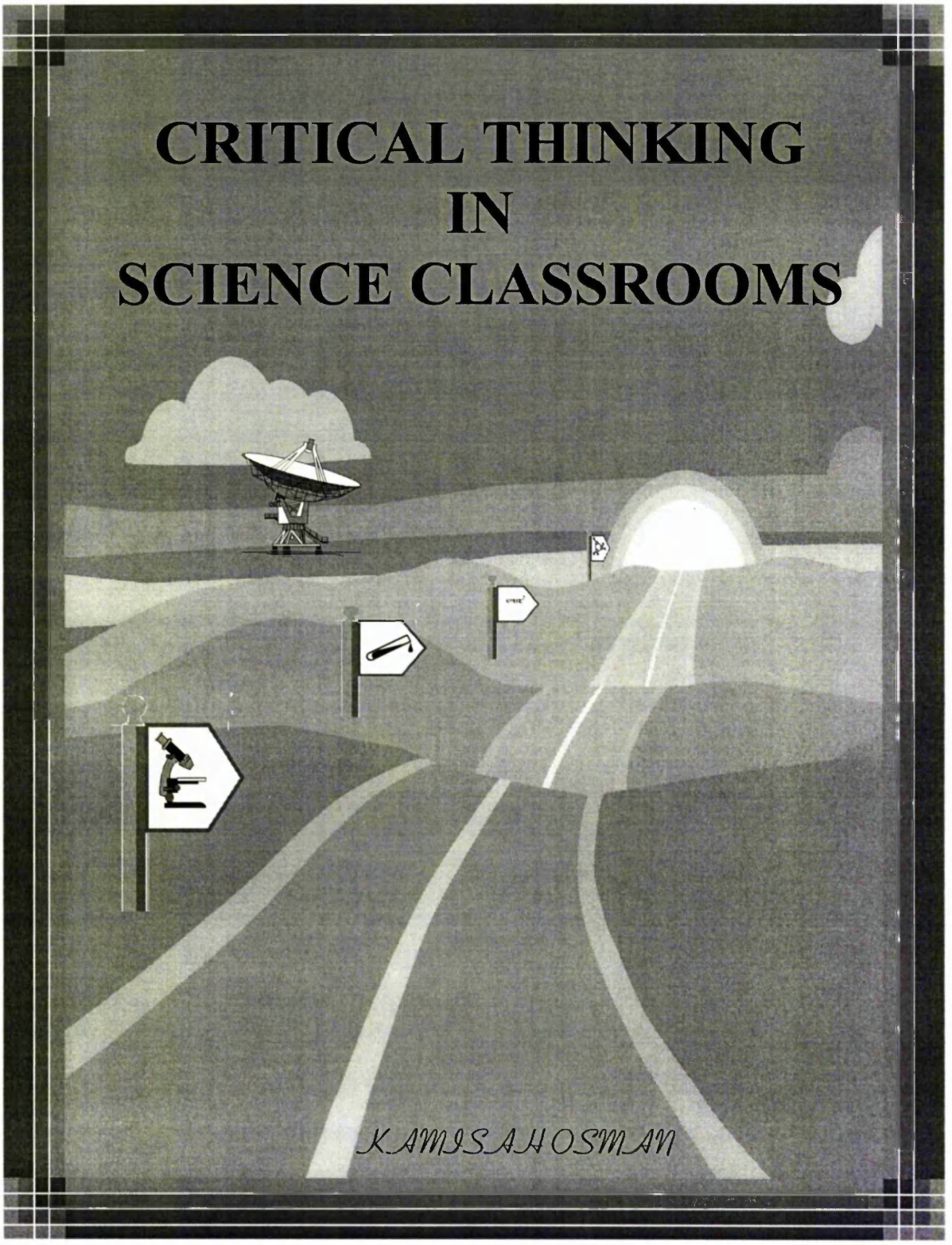
CONCEPT MAP
REPRESENTING THE CONTENT OF THE
SELF-INSTRUCTIONAL MATERIAL

FIGURE 1 CONCEPT MAP REPRESENTING THE CONTENT OF THE MI



APPENDIX G

THE SELF-INSTRUCTIONAL MATERIAL: A MODULE



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The University of Manchester

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INTRODUCTION TO THE UNIT

The unit concentrates on critical thinking in science lessons, focused especially on the role of the science teachers in promoting critical thinking skills in children. There are three main aims for this unit. Firstly, the justification of the importance of critical thinking as an educational ideal will be presented. Secondly, several models of critical thinking available in the literature will be discussed and the key concept of critical thinking will be determined. And finally, the preferred model of how to teach critical thinking will be presented and guidance of how to apply the model in science classroom made.

ESSENTIAL READING

Ennis, R.H. (1987). A Taxonomy of Critical Thinking Dispositions and Abilities. In J.B. Baron and R.J. Sternberg (eds). *Teaching Critical Thinking: Theory and Practice*. New York: W.H. Freeman and Co.

Ennis, R.H., and Norris, S.P. (1989). *Evaluating Critical Thinking*. California: Midwest Publication.

Beyer, B.K. (1988). *Developing a Thinking Skills Programme*. Boston: Allyn and Bacon.

McPeck,J. (1981). *Critical Thinking and Education*. Oxford: Martin Robertson and Co.

Meyers, C. (1987). *Teaching Children to Think Critically*. London: Jossey-Bass Pub.

Salleh, K. (1995). *Masyarakat Saintifik dalam Binaan*. Kuala Lumpur: Hazrah Enterprise

Scheffler, I. (1973). *Reason and Teaching*. New York: Bobbs-Merrills.

The New Integrated Secondary Science Curriculum (Form One, Two, and Three)

UNIT CONTENT AND OVERVIEW

Each chapter contains:

An **Introduction** to summarise what the chapter contains.

Exercises which are an integral part of the learning material. They help you reflect, assimilate and learn from the material. You must complete them.

Assignments These are pieces of work, similar to exercises, which help you learn from the material and your own experience. The only difference is that they cannot always be completed whilst you are undertaking to read the material. You may need to gather information, e.g. The syllabus of the Integrated Secondary School Science Curriculum or actually teach a class as part of the assignment. Assignments, although at the end of the chapter, are related to a particular section. These sections are indicated in the chapter content list.

Three or four **objectives** for you to achieve.

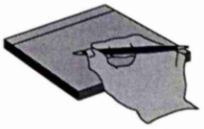
A **summary** which reinforces what has been said and leads you forward.

A **keypoint** to help you revise and consolidate your learning

KEY TO ICONS

Certain symbols are used to mark activities so that you know what they involve. These are shown below:

This is an exercise that helps you to reflect, assimilate and learn form the material. You must complete all of them.



This is an area that you should address in your journal/notes

This is an exercise or assignments which you should use as a point of discussion with your colleague and your tutor

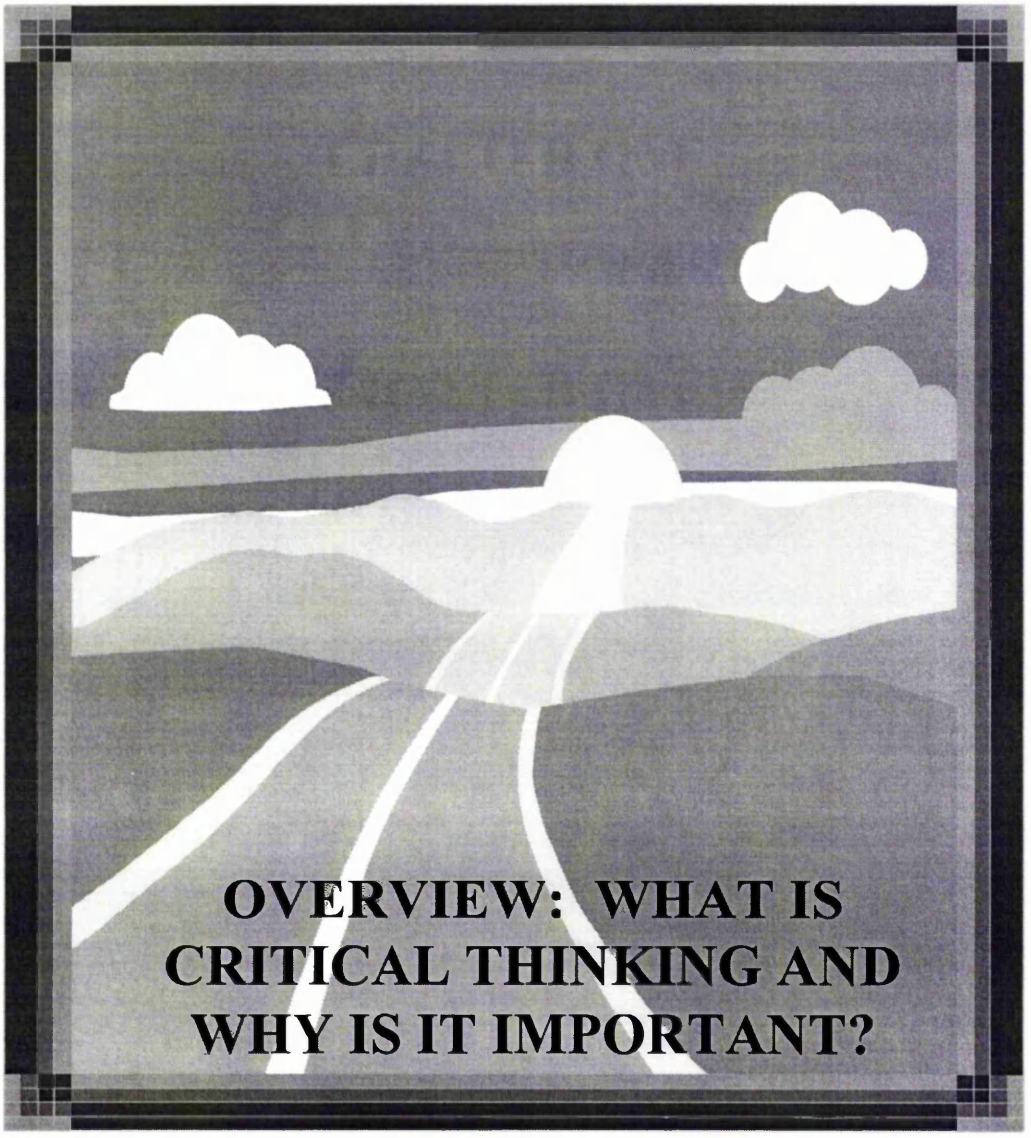
This is an assignment which require some written work

An assignments which requires you to do an observation on a class, pupil or teacher. It may involve a colleague or your tutor observing you

This is a keypoint to help you revise and consolidate your understanding

This is a summary of the whole unit which reinforces what has been discussed

CHAPTER ONE



Objectives By the end of this chapter you will be able to:

- Justify why critical thinking is essential for Science Education in Malaysia
- Define critical thinking, using your own words, based on a commonly used definition of critical thinking
- Describe the evolution of critical thinking
- Identify how critical thinking is similar to, and different from, problem solving.

Contents

1.1 General Introduction

1.2 The Justification of Critical Thinking as an Educational Ideal

1.3 The Conceptions and Definitions of Critical Thinking

1.3.1 Critical Thinking: Some Common Definitions

1.3.2 Definition of Critical Thinking for Science Education

1.3.3 Further Elaboration of Ennis's Conception of Critical Thinking

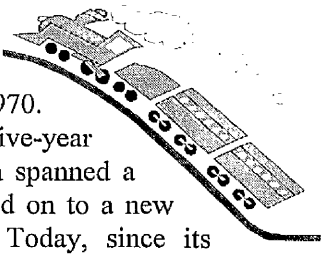
1.3.4 The Relationship between Critical Thinking and Problem Solving

1.3.5 Ennis's Definition of Critical Thinking and the Islamic Context of the Integrated Secondary School Science Curriculum

1.4 Summary

Assignment Definition of Critical Thinking

1.1 GENERAL INTRODUCTION



Malaysia has come a very long way since its first five-year socio-economic plan which set the direction and pace for national development in 1970. Encouraged by its success in implementing this five-year plan as well as the New Economics Policy, which spanned a twenty-year period since 1970, Malaysia has moved on to a new and more challenging phase in nation-building. Today, since its official launch in 1991, Malaysia is guided by Vision 2020. The architect of Vision 2020, YAB Dato' Seri Dr Mahathir Mohamad, the Prime Minister of Malaysia, in his speech "Malaysia: The Way Forward" has stated that Malaysia will emerge as a fully developed nation by the year 2020. The mission statement of the Vision 2020 states that:

> *"By the year 2020, Malaysia is to be a united nation, with a confident Malaysian Society, infused by strong moral and ethical values, living in a society that is democratic, liberal and tolerant, caring, economically just and equitable, progressive, and prosperous, and in full possession of an economy that is competitive, dynamic, robust and resilient"*[1]

It is almost axiomatic that human resource development is the key towards a developed and industrialised society[2]. The history of human civilisation has also taught us that the character and strength of a nation is invariably linked with the quality and attributes of its citizenry. Thus, in order to successfully develop economically, politically, socially, spiritually, psychologically and culturally, the Prime Minister of Malaysia also stressed the importance of human resource development by stating that:

> *"... it is blindingly clear that the most important resource of any nation must be the talents, skills, creativity and will of its people. What we have between our ears, at our elbow and in our hearts is much more important than what we have below our feet and around us. Our people are our ultimate resource. Without a doubt,... Malaysia must give the fullest emphasis possible to the development of this ultimate resource"*[3]

Realising the importance of human resource development in the context of a mission to produce a mature Malaysian society which is diligent and resourceful and which can initiate, direct and propel industrial growth, the Prime Minister outlined nine central strategic challenges to be faced by Malaysians. One of the challenges is to establish a scientific and progressive society - a nation that is innovative and forward-looking, one that is not only a consumer of technology but also a contributor to scientific and technological civilisation of the future. In an effort to manifest such aspiration into action, a number of follow-up actions have been proposed in the Sixth Malaysia Plan and The Second Long Term

---

[1] Mahathir, M. (1993). Malaysia: The Way Forward. In A.S. Abdul Hamid (eds). *Malaysia's VISION 2020: Understanding the Concepts, Implications and Challenges*. Selangor: Pelanduk Publications.

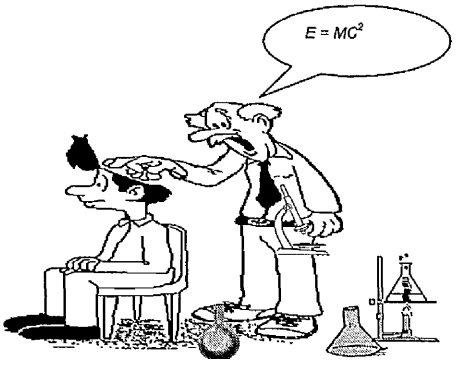
[2] Abdullah, O.Y. (1993). Human Resource Development: The Key to a Developed Society. In A.S. Abdul Hamid (eds). *Malaysia's VISION 2020: Understanding the Concepts, Implications and Challenges*. Selangor: Pelanduk Publications.

[3] Mahathir, M. (1993).*ibid.*

Perspective Plan and among these are to readjust Science and Technology (S&T) education to cater for creativity among the younger generation and to produce more highly qualified graduates and researchers[4].

Thus it is Malaysians, in attempting to realise this aspect of the aspiration of Vision 2020, will employ the scientific and technological education programmes envisioned in the Second Long Term Perspective Plan and Sixth Malaysia Plan. Additionally, in order to realise the potential of "what Malaysians have between their ears, at their elbow and in their heart", will in turn require every Malaysian to think creatively and analytically and at the same time be capable of solving problems and making decisions.

The endeavour to stimulate people to think effectively has been part of educationalists' agenda for centuries since the era of Plato, Aristotle and in more recent times Dewey and many others[5]. In the Quran, ALlah does want man to reflect and think about the physical environment he inhabits (e.g. the alternation of night and day) and the physical entities in his surroundings (e.g. stars, moon, wind and clouds) in order to be aware of and appreciate the greatness of the Creator[6]. During the last century, particularly in science education, the teaching of content became dominant.



However, the last twenty years have seen the rebirth of the idea that schools should teach children the skills of higher order thinking[7].

Realising these facts and the aspirational missions as envisioned in Vision 2020, Sixth Malaysia Plan and Second Long Term Perspective Plan, an effort should be made to nourish children with an ability to perform higher order thinking operations. Analysis of the Integrated Secondary Science Curriculum indicates that the acquisition of thinking and problem solving skills is indeed

---

[4] Noordin, A.B and Hasan, S. (1993). *Innovative Thinking among Scientists in Malaysian Context*, Paper Presented at The International Convention on Excellence Thinking, National University of Malaysia, Malaysia.

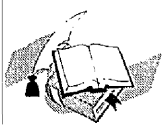
[5] Mann, L. (1979). *On the Trail of Process*. New York: Grune and Stratton

[6] *Al Quran*, 2:164.

[7] Baron, J. (1993). Why Teach Thinking? An Essay. *Applied Psychology: An International Review*, *42*(3), 191-237.

emphasised[8]. However, the provision of appropriate curriculum *per se* is not enough. In order to disseminate curriculum innovation, it is important that the ideas and rationale underlying the innovation be understood by those implementing it[9]. Since the teachers are the key players in the innovation process[10], they must understand how to infuse critical thinking in their teaching.

1.2 THE JUSTIFICATION OF CRITICAL THINKING AS AN EDUCATIONAL IDEAL



Exercise

The aims, objectives and emphases of the Integrated Secondary School Science Curriculum are designed to promote "a scientific way of thinking", "a scientific approach to problem solving", "a desirable attitude towards science" and "awareness of the importance of science in human affair".

Describe how critical thinking can provide the means by which a number of implications of the New Integrated Secondary Science Curriculum may be realised.

[8] Osman, K. (1995), *Constructing a Malaysian Science Curriculum: Retaining Tradition in a Context Of Change*, Unpublished Masters Dissertation, University of Manchester

[9] Hurd, P.d. and Gallanger, J.J. (1969), *New Direction in Elementary Science Teaching*, California, Wadsworth Publishing Co.

[10] Horsley, S.L. and Stiegelbauer, S. (1991), Using Knowledge of Change to Guide Staff Development, in Leiberman, A. and Miller, L. (eds), *Staff Development for Education in the '90s: New Demand, New Realities, New Perspectives,* New York, Teacher College Press

Feedback

In order to achieve the aims, objectives and emphases of the Integrated Secondary School Science Curriculum, individuals need to be trained as thinking beings who can be educated to make appropriate life decisions which in turn, enable them to contribute to a democratic society. Critical thinking plays a vital role in providing means by which a number of implications of the Integrated Secondary School Science Curriculum may be realised: i) Self-sufficiency and preparation for adulthood, ii) Initiation into the rational traditions, and iii) Critical thinking and democratic living

Exercise

Quickly skim through all the topics of the Integrated Secondary School Science Curriculum (Form One, Two and Three). Select all the main topics which highlight controversial issues (e.g. pollution) that can be debated and opened to classroom discussion. Do you think this kind of activity will encourage children to think critically?

1.3 THE CONCEPTIONS AND DEFINITIONS OF CRITICAL THINKING

So then, how is critical thinking defined? First, I'll present you with a one-word answer; then we'll look at some commonly used definitions.

A synonym

If you ever hear, "Give me one word that explains critical thinking"; the best word to offer is *reasoning*. Children in the elementary school today should be learning "4 R's" instead of three: Reading, 'Riting, 'Rithmetic, and *Reasoning*. Starting from kindergarten, children should learn the *how to's* of effective reasoning (for example; how to gain insight to solve problems and to make wise decisions). This "fourth R" needs to be stressed throughout the primary and secondary schools. Tomorrow's world will be full of people who learned *reasoning skills*, or critical thinking skills, from a very early age.

Reasoning - now you have a synonym for critical thinking. However, because reasoning is a highly individualised, complex activity that involves distinct ideas, emotions, and perceptions, lets move on to a more substantial discussion.

Exercise

List the names of leaders in the fields of education, psychology and psychology who involved in the study of critical thinking.

- ☐
- ☐
- ☐
- ☐
- ☐
- ☐

There are many individuals who have contributed towards the development of conception and definition of critical thinking. Amongst all are John Dewey, Edward Glaser, John McPeck, Robert Ennis etc.

1.3.1 Critical Thinking: Some Common Definitions

Throughout the century, leaders in the fields of education, psychology and philosophy (e.g. Dewey 1916; Glaser 1941; McPeck 1981; Beyer 1987; Ennis 1982; 1987; Paul 1990) have presented us with a spectrum of definitions of critical thinking.

In the early part of this century, for example, John Dewey, in *How We Think*, seminally defined the essence of critical thinking as "suspended judgement", or

✦ *John Dewey*

"healthy scepticism"[11]. Later (1933) he included the concept of "reflective thought" within his definition. For Dewey, reflective thought entails "active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusion to which it tends"

✦ *Edward Glaser*

A quarter of century later, Edward M. Glaser, one of the authors of the Watson-Glaser Critical Thinking Appraisal Test, defined critical thinking as "an attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences; knowledge of the methods of logical enquiry and reasoning; and some skills in applying these methods"[12]. The critical thinker, as conceptualised by Glaser, must make a persistent effort to examine any belief or supposed form of knowledge in the light of evidence.

✦ *Beyer*

Towards the end of the 20th century, Beyer (1988) interestingly distinguishes critical thinking from "micro thinking skills" such as those illustrated in "Bloom's Taxonomy" and those typically taught in logic and philosophy (inductive, deductive, and analogical reasoning). Beyer also differentiates critical thinking from higher level "thinking strategies" such as problem solving and decision making which he argues are more complex cognitive tasks aimed at the process of developing support to formulate a particular solution to a problem. Such higher order "thinking strategies" consists of a hierarchical sequence of subordinate procedures for example, (a) the recognition of a problem; (b) represent a problem; (c) devise/choose a solution plan; (d) execute the plan; (e) evaluate the solution)[13].

Beyer conceptualises critical thinking as a repertoire of specific operations, situated between micro thinking skills and major thinking strategies in terms of their complexity and function. These critical thinking skills may be used independently or in any combination and order (in contrast to micro thinking skills and thinking strategies where each level subsumes those antecedent to it). In Beyer's list, critical thinking skills include the ability to: distinguish between verifiable facts and value claims, distinguish relevant from irrelevant information, determine the factual accuracy of a statement, determine the credibility of a source, identify ambiguous claims or arguments, identify unstated assumptions, detect bias, identify logical fallacies, recognise logical inconsistencies in a line of reasoning, and determine the strength of an argument or claim[14]. Therefore, there is seen to exist a hierarchical order of micro thinking skills, critical thinking operations and thinking strategies (the latter including problem solving and decision making). Such contentions imply that critical thinking will necessarily include micro thinking skills and as argued by Ziedler et. al. (1992)[15], is a necessary condition for a successful execution of problem

---

[11] Dewey, J. (1910). How We Think, Lexington: Mass: Heath.

[12] Glaser, E.M. (1941). *An Experiment in the Development of Critical Thinking*. New York: Bureau of Publications, Teachers College.

[13] Beyer, B.K. (1988). *Developing a Thinking Skills Programme*. Boston: Allyn and Bacon Inc.

[14] Beyer, B.K. (1988). *op.cit*, p.57

[15] Ziedler, *et. al.* (1992). Fallacies and Children Discourse: Conceptualising the Role of Critical Thinking in Science Education. *Science Education*, *76*(4), 437-450.

solving strategies. **TABLE 1.1** depicts the hierarchical structure of major thinking operations as advocated by Beyer (1990).

✦ *D'Angelo*

A dynamic model of critical thinking is based upon Ennis's (1962) concept of critical thinking as "the correct assessing of statements[16]". D'Angelo developed this line of thought on critical thinking as "the process of evaluating statements, arguments, and experiences"[17]. Critical thinking so defined would consist of all the attitudes and skills used in the evaluating process. A significant feature of D'Angelo's work is his ignoring of the role of knowledge of facts and information in the execution of any critical thinking operation and this rejection of the importance of knowledge as a pre-requisite for the development of critical thinking is clearly inconsistent with several other authors (e.g. Ennis 1962, Glaser 1941). It is the concentration by D'Angelo on skills and attitudes, which make his ideas significant in the evolution of the concept of critical thinking.

✦ *Mc Peck*

McPeck (1981) defines critical thinking as "the appropriate use of reflective scepticism within the problem under consideration"[18]. He suggests that the building blocks of critical thinking are the skills and propensity to engage in an activity with reflective scepticism, and claims that critical thinking is a skill that must be developed and emphasised within the knowledge of a particular domain: As McPeck has it:

> Critical thinking is always thinking about **"X"**, it follows that critical thinking is intimately connected with other fields of knowledge. Thus, the criteria for the judicious use of scepticism are supplied by the norms and standards of the fields under consideration.[19]

Thus, it can be implied, skills and propensity are in themselves not enough. Critical thinking also entails the knowledge background of the person. The phrase "reflective scepticism" refers to both the purpose and the quality of thinking in question. Scepticism, as argued by McPeck, promotes the resolution of a problem. But scepticism by itself in insufficient. An element of reflectivity is required to inject a level of deliberation (for instance, capable of offering a plausible alternative) into the act of critical thinking. McPeck's formal definition of critical thinking is as follows:

> Let **X** stands for any problem or activity requiring some mental effort; Let **E** stand for the available evidence from the pertinent field or problem area; Let **P** stand for some proposition or action within **X**.
> Then, we can say a children **S** is a critical thinker in area **X**, if **S** has the disposition and skill to do **X** in such a way that **E**, or some subset of **E**, is suspended as being sufficient to establish the truth or viability of **P**[20]

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[16] Ennis, R.H. (1962). A Concept of Critical Thinking. *Harvard Educational Review*, *32*(1), 81-111

[17] D'Angelo, Edward (1971). *The Teaching of Critical Thinking*, Amsterdam: BR Grubbier.

[18] McPeck, J. (1981). *Critical Thinking and Education*. Oxford: Martin Robertson and Co.

[19] McPeck, J.(1981). *op.cit.*, p.7

[20] McPeck, J. (1981). op.cit., p.9

TABLE 1.1

MAJOR THINKING OPERATIONS AS ADVOCATED BY BEYER

THINKING STRATEGIES

Problem Solving

Recognise a problem
Represent the problem
Devise / choose solution plan
Execute the plan
Evaluate the solution
Evaluate the solution

Decision Making

Define the goal
Identify alternatives
Analyse alternatives
Rank alternatives
Judged highest-ranked alternatives
Choose "best" alternatives

Conceptualising

Identify examples
Identify common attributes
Classify attributes
Interrelate categories of attributes
Identify additional examples
Modify concepts attributes / structure

CRITICAL THINKING SKILLS

Distinguishing between verifiable facts and value claims
Distinguishing relevant from irrelevant information, claims or reasons
Determining the factual accuracy of a statement
Determining the credibility of a source
Identifying ambiguous claims or arguments
Identifying unstated assumptions
Detecting bias
Identifying logical fallacies
Recognising logical inconsistencies in a line of reasoning

MACRO THINKING SKILLS

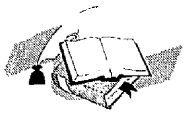
Recall
Translation
Extrapolation
Application
Analysis
Synthesis
Evaluation

Reasoning

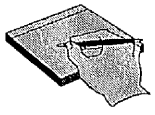
Inductive
Deductive
Analogical

✦ *Ennis*

Ennis (1987) uses three key concepts to define critical thinking; reflective, reason and focus. The combination of these three concepts configure a working definition of critical thinking as "reasonable reflective thinking that is focused on deciding what to believe or do"[21]. For Ennis, a critical thinker is someone who is caring to get something right (seeking alternatives, endorsing a position to the extent that it is justified, and being well-informed); representing a position honestly (being clear, determining focus, offering reasons, accounting for the total situation, seeking precision, awareness of basic beliefs, seriously consider others' viewpoints); and caring about the dignity and worth of every person (listening to others viewpoints and reasons, avoiding intimidation and confusion, and concern for others' welfare). Ennis also lists twelve abilities of the critical thinker which he groups into those which involve clarification, metacognitive abilities and auxiliary critical thinking abilities.



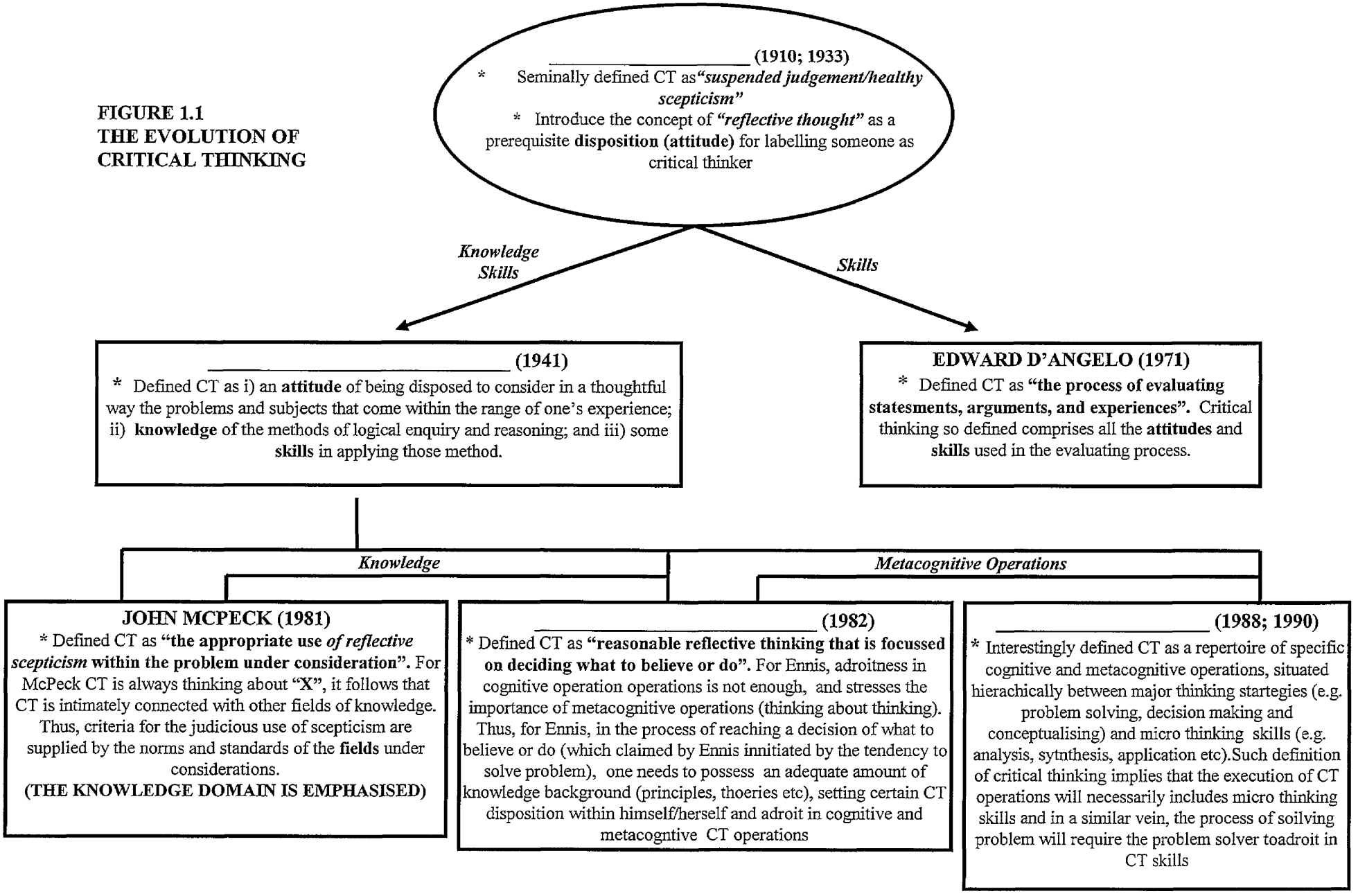
Exercise



Literature on critical thinking indicates that the entire concept has undergone a process of evolution. Beginning with Dewey's seminal concept of critical thinking, the ideas of Glaser and D'Angelo then appear in a transitional stage and those are further developed by McPeck, Ennis and Beyer. Read again the definition of critical thinking discussed in the previous section and complete FIGURE 1.1 which illustrates the evolution of critical thinking definitions

[21] Ennis, R.H. (1987). A Taxonomy of Critical Thinking Dispositions and Abilities. In J.B. Baron and R.J. Sternberg (eds) *Teaching Thinking Skills: Theory and Practice*, New York, W.H.

FIGURE 1.1
THE EVOLUTION OF CRITICAL THINKING



1.3.2 Definition of Critical Thinking for Science Education

In search of a definition that's suitable to be applied in the science classrooms, I reviewed the literature, considered the nature of science as a subject, the Philosophy of Education and Islamic Working Paradigm that underpin the implementation of Science Education in Malaysia. The most suitable definition is based on Ennis's work:

"Critical thinking is reasonable, reflective thinking that is focused in deciding what to believe or do"

Before discussing the precise, one-sentence definition of critical thinking as advocated by Ennis (1987), let us first consider these two followings scenarios:

Scenario One:

It is Tuesday. Alice is driving down the highway and the following is running through her mind: "I'll sure be glad when this week is over. I have so much to do. . .Chemical Analysis on Wednesday. . . assignment due on Thursday . . . part-time work tonight. . . I really want to get a hair cut . . . Do I really have to shop tomorrow? . . . Gee, what a pleasant looking man that is on the corner . . . Oh dear, I'm really starving. Shall I stop and eat?"

Scenario Two

It's Friday. Alice had a bad week. The Chemical Analysis test was terrible. She was stressed out at work because she was worried about her paper. She finished her paper in a last-minute rush. She look ahead and feel overwhelmed with assignments and commitments. She thinks to herself, "I've got to get organised. Tomorrow morning, I'm going to sit down with my calendar and figure out what I have to do and when I'm going to do it. I'm going to write everything down, set priorities, and make up a schedule so I have some control over my life"[22]

Critical Thinking is Reasonable Thinking

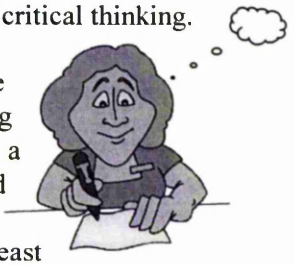
First, critical thinking is defined as *"reasonable"* thinking. This implies that critical thinking is a purposeful mental activity that relies heavily upon the use of reasoning. Since critical thinking is purposeful, reasonable thinking, a critical thinker must set his/her goals deliberately and revise the goals where necessary. Without goals or good reasons for action, one could end up acting arbitrarily and unreasonably. Good thinking is therefore not arbitrary; however, critical thinkers must be open to multiple possibilities and consider a number of alternative routes to their objectives. Scenario One illustrates aimless,

[22] Adapted from Alfaro-LeFevre, R. (1995). *Critical Thinking in Nursing: A Practical Approach.* United States of America: W.B. Saunders Co.

unreasonable (illogical) thinking with images and ideas drifting arbitrarily through Alice's mind. Whereas in Scenario Two, Alice has set herself appropriate objectives and sits down to think critically about the reasons that surround her disorganised life.

Critical Thinking is Reflective Thinking

Second, critical thinking is defined as *"reflective"* thinking. The element of reflectivity allows retrospective examination of previously reasoned thoughts and subsequent actions. McPeck (1981)[23] argues that an element of reflectivity is essential to inject possible alternatives into the act of critical thinking. Referring to *Scenario Two*, was Alice reflective in Planning her time management?. Judging from what she has done (i.e. sitting down with her calendar, writing everything down, setting priorities and making up a schedule of what she has to do) she has consciously and deliberately planned her time management, and it can be concluded that Alice's action show that she was at least somewhat reflective.



Critical Thinking is Focused Thinking

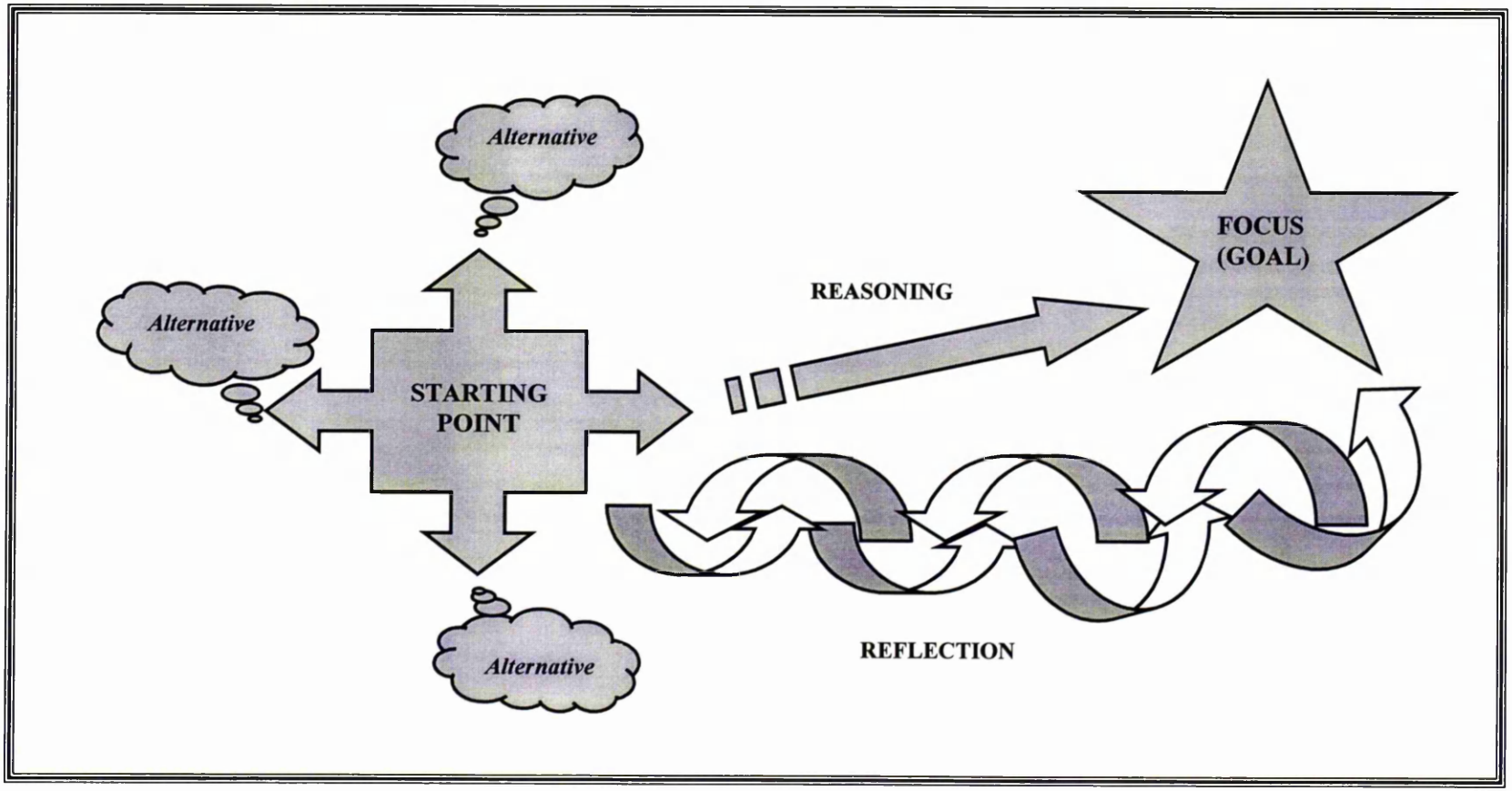
Third, critical thinking is said to be *"focused"* thinking. It is axiomatic that first the thinker has to have something to think about. Critical thinkers must focus their minds on the purposes or goals of the thinking process. What are they thinking about? Only when a goal has been set or a problem recognised can appropriate reasoned and reflective thought follow.

FIGURE 1.2 illustrates the interrelation of these three main operations that underpinned the process of critical thinking.

[23] McPeck, J. (1981). *Ibid.*

FIGURE 1.2

SHEMATIC DIAGRAM OF CRITICAL THINKING MAIN OPERATIONS



Exercise

Please complete this following statement by using the words listed below:

reflection	**multiple posibilities**	**a number of alternatives**
reasoning	**focus**	**reflective**

The definition of critical thinking incorporates the process of thinking itself. The processes involved are _____, _____, and _____ but not necessarily in that order.
Thus, a critical thinker is someone whose thinking operation is directed by his goal. After the goal has been set, he will consider _____, and be open to _____. Equipped with his reasoning abilities, a critical thinker then moves towards the achievement of his goal. However, to be able to examine retrospectively his reasoned thought and subsequent actions, a critical thinker must _____ in his thinking.

1.3.3 Further Elaboration of Ennis's Conception of Critical Thinking

Critical thinking is a mental process that is focused on deciding what to believe or do. In making decisions, humans rely on information, background knowledge, and previously accepted conclusions. These elements form ***the basic support*** for the decision. The link between the basis for the decision and the decision itself is the process called ***inference.*** Thus, decisions are inferred on the basis of known information and previously accepted conclusions.

FIGURE 1.3 depicts the logical relationships in the critical thinking process. Although **FIGURE 1.3** implies the direction of the process is from bottom to top, this does not mean that critical thinking in any practical sense necessarily follows an ordered, linear path. Indeed, critical thinking can be proceed in many directions and can stop, restart, and retrace.

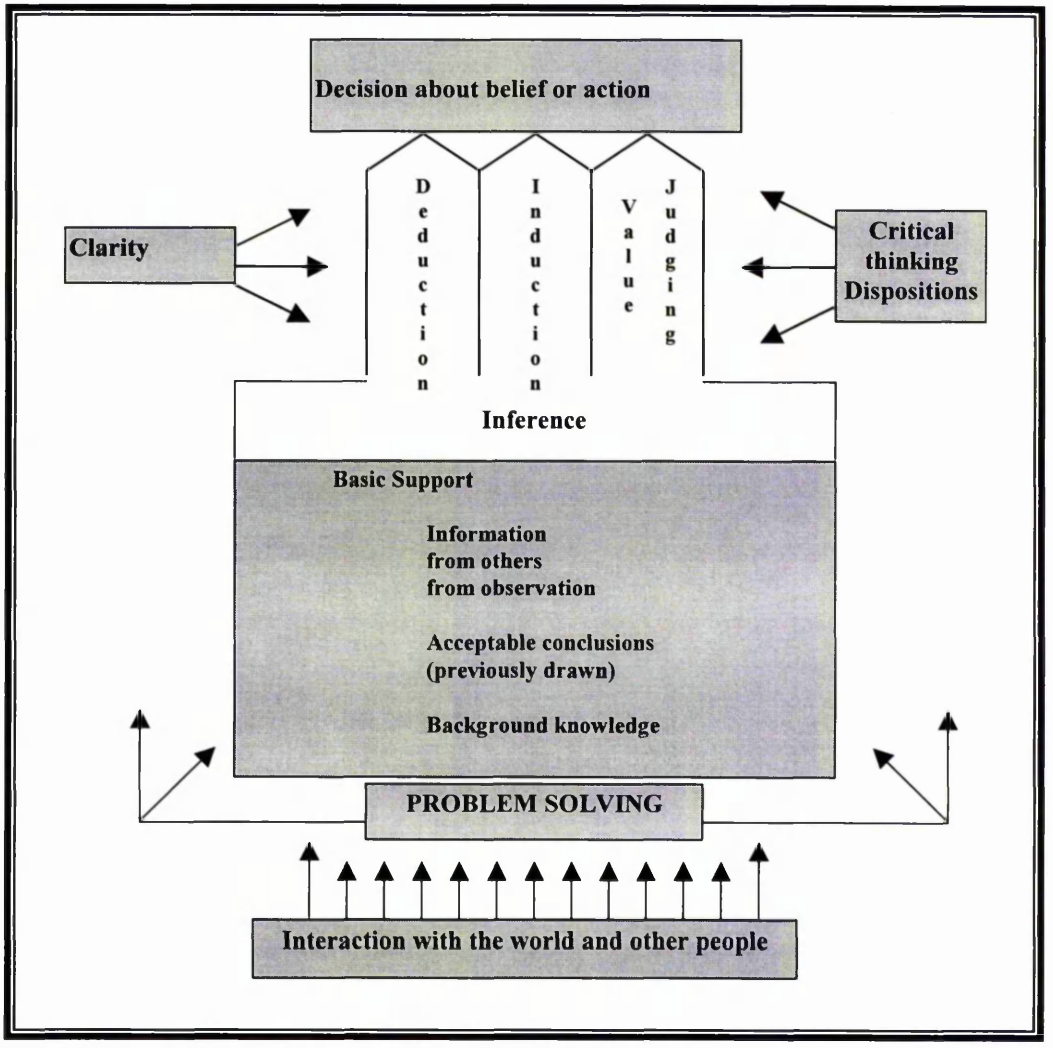
The Problem Solving box near the bottom of **FIGURE 1.3** indicates that the process of critical thinking is viewed broadly as an element of problem solving. The process of critical thinking ends in a decision about belief or action indicated by the Decision box at the top of the figure. The Interaction box at the bottom of the figure indicates that the whole process of reaching a decision usually rests in a context of interaction with the world and other people. The

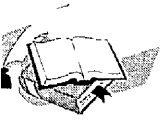
basic Support box acts as the starting point of critical thinking, which consists of information from others and observation, previously accepted conclusions and background knowledge. The Inference columns indicate three basic type of inference processing which result in the final decisions.

The points in the column indicate the direction of the logical inference. The Disposition box and the arrows depict the need to diffuse critical thinking dispositions throughout the whole critical thinking processes. Finally, the Clarity box and the arrows emanating from it illustrate how a concern with clarity must permeate the process of critical thinking.

FIGURE 1.3

A PICTORIAL REPRESENTATION OF CRITICAL THINKING





Exercise

Refer back to FIGURE 1.3 and:

Discuss several ways in which critical thinking is similar to, and different from problem solving

As indicated earlier, critical thinking is broadly viewed as problem solving. In many ways, critical thinking is like an upgraded version of the problem solving method. However, as a method, problem solving has its limitations. For example, problem solving starts with a problem and ends with a solution[1]. Critical thinking, on the other hand, is more *open-ended, focusing on continuous improvement*, regardless of whether or not a problem exists. Critical thinking, unlike problem solving may be triggered by positive events. For instance, if we see something good happen, and we say, "That is really great!" If we're critical thinkers, we should be thinking, "We must find a way to make this happen more frequently (or for everybody)". If we stayed in our problem-solving mode, it is argued that we might miss these positive triggers, and lose opportunities to progress. Clearly by thinking critically, we are engaging in a process that involves more than solving a problem.

[1] Pizzini, et.al. (1989). A Rationale for and the Development of a Problem Solving Model of Instruction in Science Education,.*Science Education*, *73*(5), 532-534

1.3.4 The Relationship between Critical Thinking and Problem Solving

The term "problem solving", just like the terms "scientific method", "scientific thinking", "critical thinking" and "inquiry skills" is used frequently in science education literature. Although some distinctions are made amongst them, it is clear that all of them have reference to some portion of the ability to solve problems (Champagne and Klopfer 1977), and as Larkin (1979) asserts:

> "All the sciences, both pure and applied, are centrally concerned with developing and systematising knowledge useful for solving various kind of problem. Hence, education in the sciences must address the crucially important task of teaching children to become proficient problem solvers[2]"

The relationship between critical thinking and problem solving is consistent with Ennis's generalisation (see also **FIGURE 1.3**), and such a conception of critical thinking would appear to be in harmony with the ultimate aims of the Integrated Secondary School Curriculum science programme; i.e.

> *.. to provide children with knowledge and skills in science, to develop their* ***scientific thinking*** *as well as to inculcate good moral values in them. This will enable children to understand and appreciate science and its application to everyday life as well as in national development. It seeks also to produce responsible citizens who are able to participate in* ***problem solving*** *activities and* ***make decisions*** *for the well being of Man*[3]

1.3.5 Ennis's Definition of Critical Thinking and The Islamic Context of The Integrated Secondary School Science Curriculum

For Ennis, the process of solving problems will end in a decision about a belief or an action, a philosophy which coincides with the ultimate aim of NISC quoted above, that is the making of decisions for the well being of Man. Such an aim, is also a central feature of Islamic Philosophy[4] and the working paradigm that posits that Nature and Al Quran are ALlah's great endowment to Man (**FIGURE 1.4).** Through the teaching of Al Quran, Man can realise himself as the true *abd* (servant) of Allah, and through his interaction with nature[5], Man can perform his role as a *khalifah*[6] (vicegerent) of ALlah. In other words, Man is encouraged to bring about innovation within the framework of Nature, yet owe his allegiance to ALlah the Almighty. Thus, only by actualising his role as an *abd* and *khalifah* of ALlah, can Man establish himself as an *insan kamil* (complete man). The complete man, has the ability to discriminate and hence

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[2] Larkin, J.H. (1979). *Problem Solving in Physics*. Technical Report, University of California, p.191.

[3] Ministry of Education (1989). *Curriculum Development Centre*, Kuala Lumpur.

[4] Salleh, K.M. (1995). *Islamic Thought, Science and Science Education*, Kuala Lumpur: Hazrah Enterprise, p. 221.

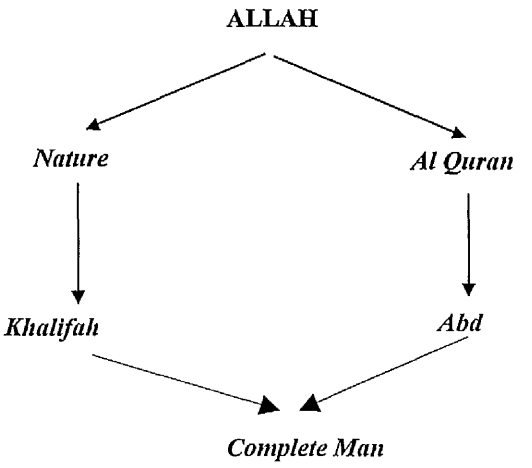
[5] Nature is a meant to be "read" and studied by Man. In it is a sign for those who think, reflect, know and understand them.

[6] Khalifah: someone who inherits the earth and has supremacy in it (Al Quran 2:30; Al Quran 6:165).

make judgements which result in the actions that he takes regarding the issues and problems that are before him.

FIGURE 1.4:

THE WORKING PARADIGM OF SCIENCE EDUCATION



Ennis's conceptualisation of critical thinking perceives the process of reaching a decision as resting in a context of interaction between an individual, and other people. Such a view is also consistent with the Islamic philosophical thoughts underpinning the ISSSC. Man, in performing his role as an *abd* and *khalifah* in this world, has to consider not only his obligation towards ALlah *(relationship between the creator and the creatures),* but also his relationship among ALlah's creation *(relationship among the creatures created).*

The Al Quran takes it as axiomatic that knowledge is a prerequisite for wisdom and power[7]. The possession of in-depth knowledge, coupled with adroitness in relevant skills, equip Man with the power to act intelligently and effectively. The nature of learning science requires certain background knowledge since science, *inter alia* is a hierarchical building of concepts. The ability to recognise and then solve scientific problems subsumes the process of science learning such as observation etc. (see also **FIGURE 1.3**). The generation of answers that will confirm or refute belief (scientific theory) or inform a decision to be taken is the ultimate aim of ISSSC, and to help children perform at this level learners must know how to self-acquire knowledge, perform activities of science either theoretically or experimentally, administer, manage and make decision about scientific activities, but more than that, grow and develop at the spiritual and affective levels. In the Islamic context, scientific method is not solely the application of the processes mentioned above, but places equal importance on other ways of knowing such as intuition and revelation.

[7] Al Quran

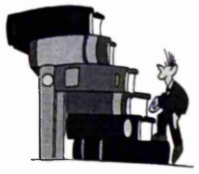
It is argued that in order for learners to become effective science problem solvers as well as critical thinkers, teachers need to not only instil the proper processes of science *per* se, but also "to produce individuals who are intellectually, spiritually, emotionally and physically balanced and harmonious, based on the a firm belief in and devotion to God"[8].

ASSIGNMENT

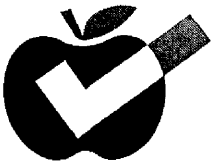
In one or two pages, define critical thinking using your own words, based on a commonly used definition of critical thinking.
In your answer, you are required to explain the difference between critical thinking and thinking in general.
Discuss your answer with your friends and tutor.

1.4 SUMMARY

By now, you should have an idea of *what* critical thinking is and *why* it is an essential element in Science Education in Malaysia. To solidify your understanding, review the following key points, and then complete the end-of-chapter exercises. Once you have done that, you'll be ready to proceed to the next chapter, which addresses the role of knowledge, skills and dispositions in instilling a critical thinking habit



[8] Ministry of Education, (1994). Curriculum Development Centre, Kuala Lumpur



KEY POINTS

➢ The importance of human resource development and cohesive effort by Malaysians to realise the aspirational Vision 2020 and the scientific and technological education programme envisioned in the Second Long Term Perspective Plan and Sixth Malaysia Plan, require every Malaysian to think critically and analytically.

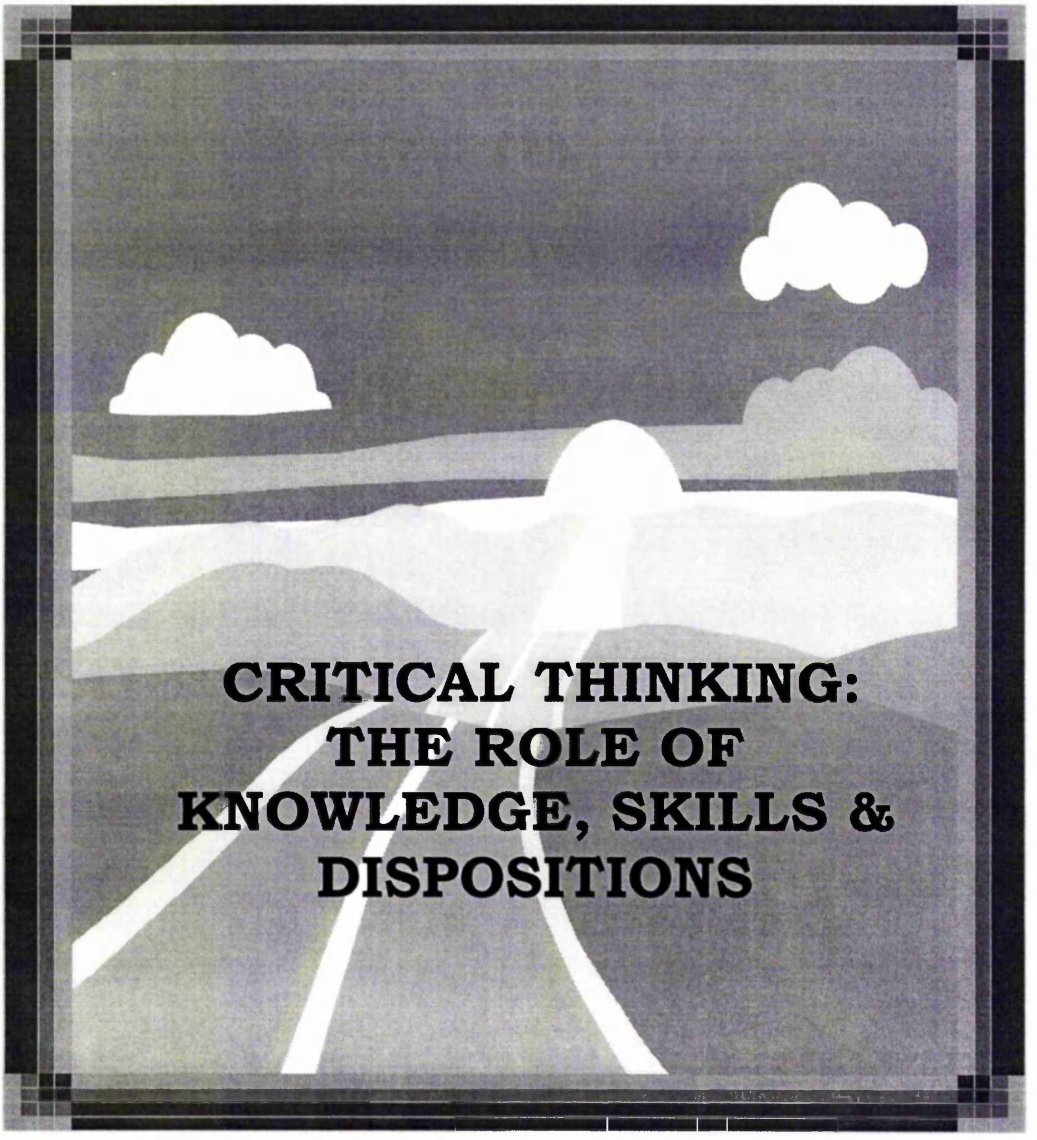
➢ Critical thinking plays a vital role by providing the means by which a number of implications in the New Integrated Secondary Science Curriculum may be realised:

i) Self-sufficiency and preparation for adulthood
ii) Initiation into the rational tradition
iii) Critical thinking and democratic living

➢ Critical thinking is *"a reasonable, reflective thinking that is focused in deciding what to believe or do"*. Such conceptualisation of critical thinking is not only suitable to be applied in the science classroom, but also consistent with the national Philosophy of Education and Islamic Working Paradigm that underpin the implementation of the New Integrated Secondary Science Curriculum.

➢ In many ways critical thinking is an "upgraded version" of the problem solving method. However critical thinking involves more than solving problems. Unlike problem solving, critical thinking may also be triggered by positive events; i.e. if we see something that works well, we need to start thinking about how to use it to our advantage.

CHAPTER TWO



Objectives By the end of this chapter you will be able to:

- Address three factors that are essential in instilling a critical thinking habit based on the knowledge gained from this module
- Explain how adequate mastery of knowledge can influence how someone thinks
- Give three main types of thinking operation and how each one can influence how someone thinks
- Identify what are the dispositions needed for someone to be a critical thinker

Contents

2.1 The Role of Knowledge, Skills and Dispositions in Instilling the Habit of Critical Thinking

2.1.1 Knowledge

2.1.2 Skills (Operations)

2.1.3 Dispositions

2.2 Summary

Assignment The Role of Knowledge (2.1.1)

2.1 THE ROLE OF KNOWLEDGE, SKILLS AND DISPOSITIONS IN INSTILLING CRITICAL HABITS OF THOUGHT

Discussion in the previous Chapter indicates that critical thinking is a complex phenomenon involving at least three major components: *knowledge*, o*perations (skills)* and *attitudes* or *dispositions*. Such a compartmentalisation of thinking requires children to possess a combination of in-depth knowledge of subject matter, skills in operating information and the attitude or disposition of critical thinkers in order to cope successfully with cognitive challenges.

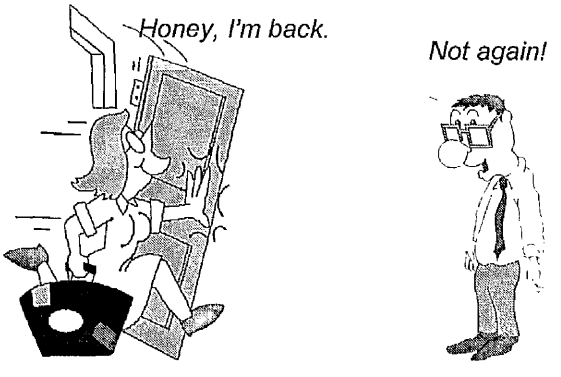
2.1.1 Knowledge

Studies comparing experts and experienced individuals in areas such as engineering, computer programming, physics, mathematics as well as reading comprehension have shown that effective thinking and problem solving depends strongly on the nature and organisation of the knowledge available to individuals. Beyer (1987)[1] distinguishes three type of knowledge: general heuristic, knowing something about the nature of knowledge and domain specific knowledge.

i) General Heuristics

General heuristics are principles based on experience that usually lead to the desired result; it is a kind of knowledge that will result in the accumulation of experience and hence guides and shapes how one goes about thinking and problem solving

> ☛ ***For instance:*** *Through their everyday life experiences, children develop an understanding about the ideas of "Forces". Forces move things. Nothing can begin to move unless a force starts it. Forces may pull, tug, heave, squeeze, stretch, twist and press, but what they all do is to move things. Thus,, if we ask children to think and make a list of 10 things forces can do, children will use their general heuristics knowledge to answer that question.*



[1] Beyer B.K. (1987). *Practical Strategies for the Teaching of Thinking*. Boston: Allyn and Bacon, Inc

ii) Knowing About the Nature of Knowledge

Knowing about the nature of knowledge includes realising that what we believe in as knowledge may be highly selective, fragmentary, interpretative, ever changing and tentative. Awareness of these aspects of knowledge appears to influence how someone goes about thinking as well as how to treat the products of other thinking.

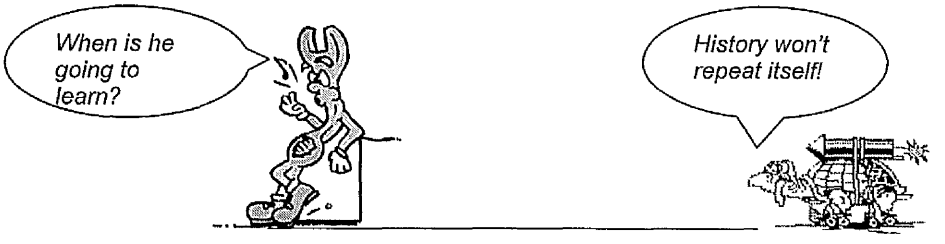
> ☛ ***For instance:*** *In the field of Science Education, children need to know about the nature of science; recognise that science is a process of thinking and a means of acquiring new knowledge and understanding the natural world).*

iii) Domain Specific Knowledge

The third dimension of the knowledge component of thinking is domain specific knowledge. This dimension of knowledge includes knowing various reliable sources of data in a particular field of knowledge, including specific analytical concepts useful for generating, organising and making sense of information in a specific field.

> ☛ ***This is exemplified in the science classroom when children are asked to solve this problem:*** *A sports car sets off due north. Its velocity goes from 0 to 30 m/s in 10 seconds. Then, the driver stamps on the brakes and stops the car in 6 seconds. What is the acceleration in each part of the journey? In order to answer such a question, knowing about the nature of knowledge and general heuristics of knowledge is not enough. Children need also to have an understanding of domain specific knowledge. In this example, children need to recall what are the concepts, principles and laws used to describe the phenomenon, and to apply these through specific mathematical operations in order to solve the problem.*

Thus, if domain specific knowledge is properly taught, it will inevitably entail higher order thinking because adequate mastery of most subjects require the use and manipulation of knowledge in subject area.



Exercise

Could you please give another example of :

i) General Heuristics

ii) Knowing about the nature of knowledge

iii) Domain Specific knowledge

2.1.2 OPERATIONS (SKILLS)

Generally thinking consists of some types of mental activity, which can be classified in terms of the operation that the mind seems to perform when engaged in the process of thinking. Literature has shown that those operations can be segregated into two general types: *cognition* and *metacognition.*

Have you ever thought about your own thinking? Thinking about your own thinking is conceptualised as the ***metacognitive*** *aspect of the thinking operation.*

Cognition consists of those operations which are used to generate and find meaning and covers most of what we have discussed so far. *Metacognition*, on the other hand, consists of those operations by which we direct and control our thinking itself. It refers to one's knowledge about, awareness of, and control over one's own mind and thinking. Basically metacognition consists of those operations involved in navigating one's effort to search and make meaning, especially the major operations of planning, monitoring and assessing one's thinking.

Therefore, any act of thinking will involve the combination of operations designed to produce meaning *(cognitive operations)* and those that direct how

the meaning is produced *(metacognitive operations)*. The act of informing children not only how to think, but how to think about their thinking strategies helps them to operationalise their thinking processes.

Exercise

Could you give example of :

i) Cognitive operations

ii) Metacognitive operations

A summary of the *cognitive* and *metacognitive* operations involve in critical thinking as conceptualised by Ennis is given in **TABLE 2. 1**

TABLE 2.1

COGNITIVE AND METACOGNITIVE OPERATIONS[2]

COGNITIVE OPERATIONS

Elementary Clarification

1. Focusing on a question
2. Analysing arguments
3. Asking and answering questions that clarify and challenge

Basic Support

4. Judging the credibility of the source
5. Making and judging observations

Inference

6. Making and judging deductions
7. Making and judging induction
8. Making and judging value judgements

Advanced Clarification

9. Defining terms and judging definitions
10. Identifying assumptions

METACOGNITIVE OPERATIONS

Strategies and Tactics

11. Deciding on an action
12. Interacting with others

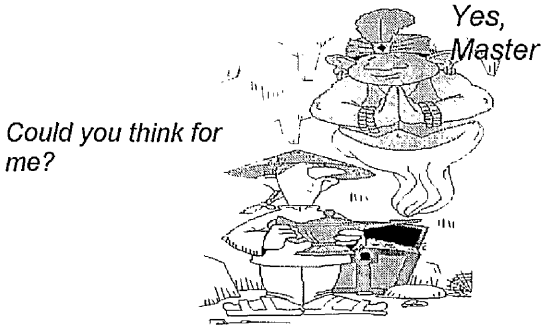
[2] Source: Adapted from Norris, P. and Ennis R.H. (1989). Evaluating Critical Thinking.

2.1.3 ATTITUDES OR DISPOSITIONS

It is argued that critical thinking requires something more fundamental even than knowledge or skills, namely a set of attitudes or dispositions which enable thoughtfulness. Experts have found the dispositions towards critical thinking to be every bit as crucial to good critical thinking as is the possession of the requisite cognitive and metacognitive skills. Generally the characteristics of "the ideal critical thinker" are as follows:

> The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgements, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit[3].

Such characterisation of critical thinking dispositions can be classified into seven major dispositions; i.e. **T**ruth seeking, **O**pen mindedness, **A**nalyticity, **S**ystematicity, Self-**C**onfidence, **I**nquisitiveness and **M**aturity. It is discipline neutral and comprises a generalisable description of the ideal critical thinker across multiple contexts and situations. **TABLE 2.2** summarises Ennis's list of critical thinking dispositions according to those seven factors that dispose a person towards using critical thinking.



[3] This is an excerpt from The Delphi Report, *Critical Thinking: A Statement of Expert Consensus for Purpose of Educational Assessment and Instruction,* (1990). Prepared for the American Philosophical Association.

TABLE 2.2: CRITICAL THINKING DISPOSITIONS

FACTOR	DEFINITION*	DESCRIPTION**
Truth-seeking	The disposition of being eager to seek the truth, courageous about asking questions, and honest and objective about pursuing inquiry even if the findings do not support one's interests or one preconceived opinions	Seek a statement of the thesis or question
Open-mindedness	The dispositions of being open-minded and tolerant of divergent views with sensitivity to the possibility of one's own bias	Seriously consider points of view other than their own; Reason from starting point which they disagree without letting the disagreement interfere with their reasoning; and Withhold judgement when the evidence and reasons are insufficient
Analyticity	The disposition of being alert to potentially problematic situations, anticipating possible results or consequences, and prising the application of reason and the use of evidence even of the problem at hands turn out to be challenging or difficult	Seek reasons; Take a position and change a position when the evidence and reasons are sufficient to do so; Take into account the total situations; Seek as much precision as the subject permits
Systematicity	The disposition towards organised, orderly, focused, ad diligent inquiry	Deal in an orderly manner with the parts of a complex whole; Keep their thinking relevant to the main point
Self-Confidence	The level of trust one places in one's own reasoning processes	Employ their critical thinking abilities Keep their thinking relevant to the main point
Inquisitiveness	Values of being well-informed, wants to know how things work, and values learning even if the immediate payoff is not directly evident	Try to be well-informed
Maturity	Targets how dispose a person is to make a reflective judgement	Look for alternatives; Are sensitive to the feelings, level of knowledge, and degree of sophistication of others

* Definition based upon the definition given in the California Critical Thinking Disposition Inventory

** The description of critical thinking dispositions based upon Ennis's list of critical thinking dispositions

Exercise

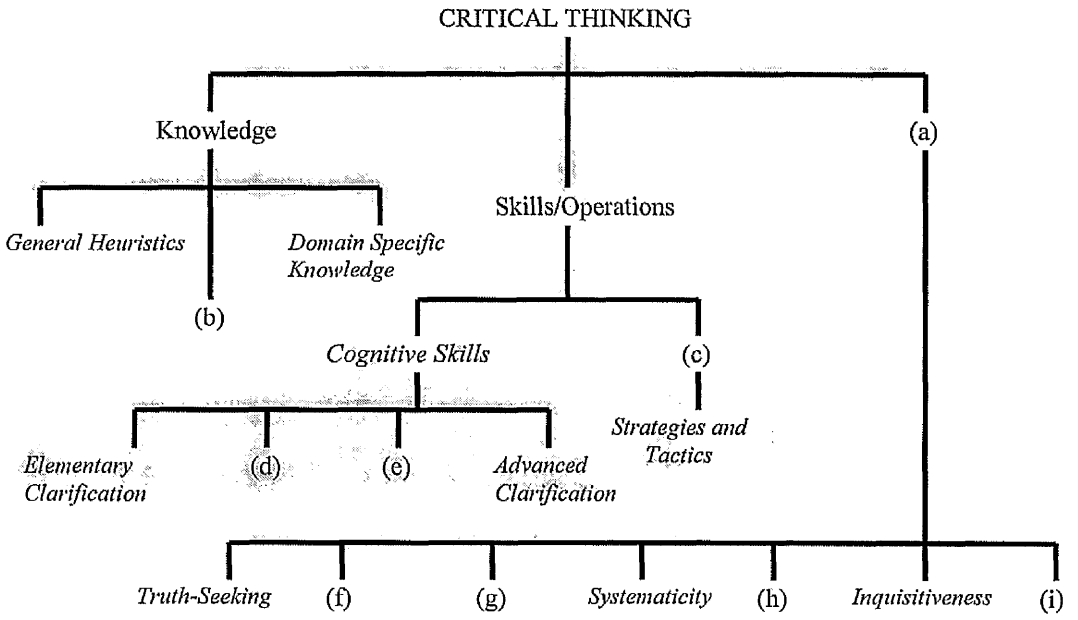


FIGURE 2.1

From your previous reading, write in the words that are missing in FIGURE 2.1. (One has been completed for you)

(a) Dispositions

(b) _____

(c) _____

(d) _____

(e) _____

(f) _____

(g) _____

(h) _____

(i) _____

ASSIGNMENT

- **Explain in one page how your knowledge level and expertise influence your ability to think critically.**

Feedback:

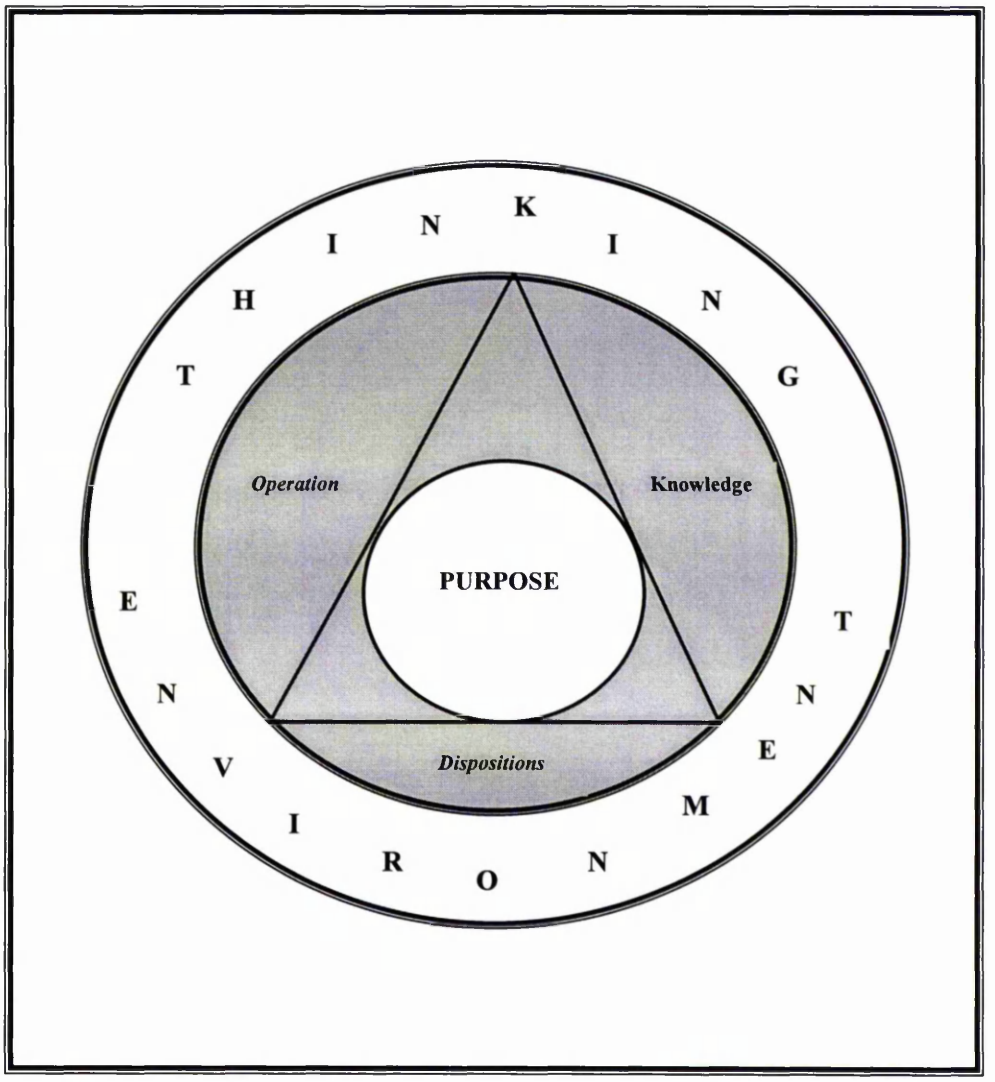
Section § 2.1.1 provides you an explanation of how knowledge of a particular domain could influence how someone thinks. In answering this question, you could also refer to other cognitive skills, for example problem solving.

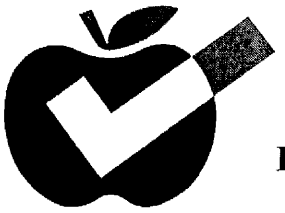
2.2 SUMMARY

The possession of *in-depth knowledge structure* and adroitness in *cognitive* as well as *metacognitive* operations will not necessarily guarantee the successful completion of the critical thinking operation. Additionally, children need to establish certain kind of *dispositions* within themselves that intrinsically motivates and inspires them to think critically. **FIGURE 2.2** illustrates diagrammatically the inter-relationship between knowledge, operations and dispositions.

FIGURE 2.2

THE CONCEPTUAL FRAMEWORK OF THINKING ENTERPRISE

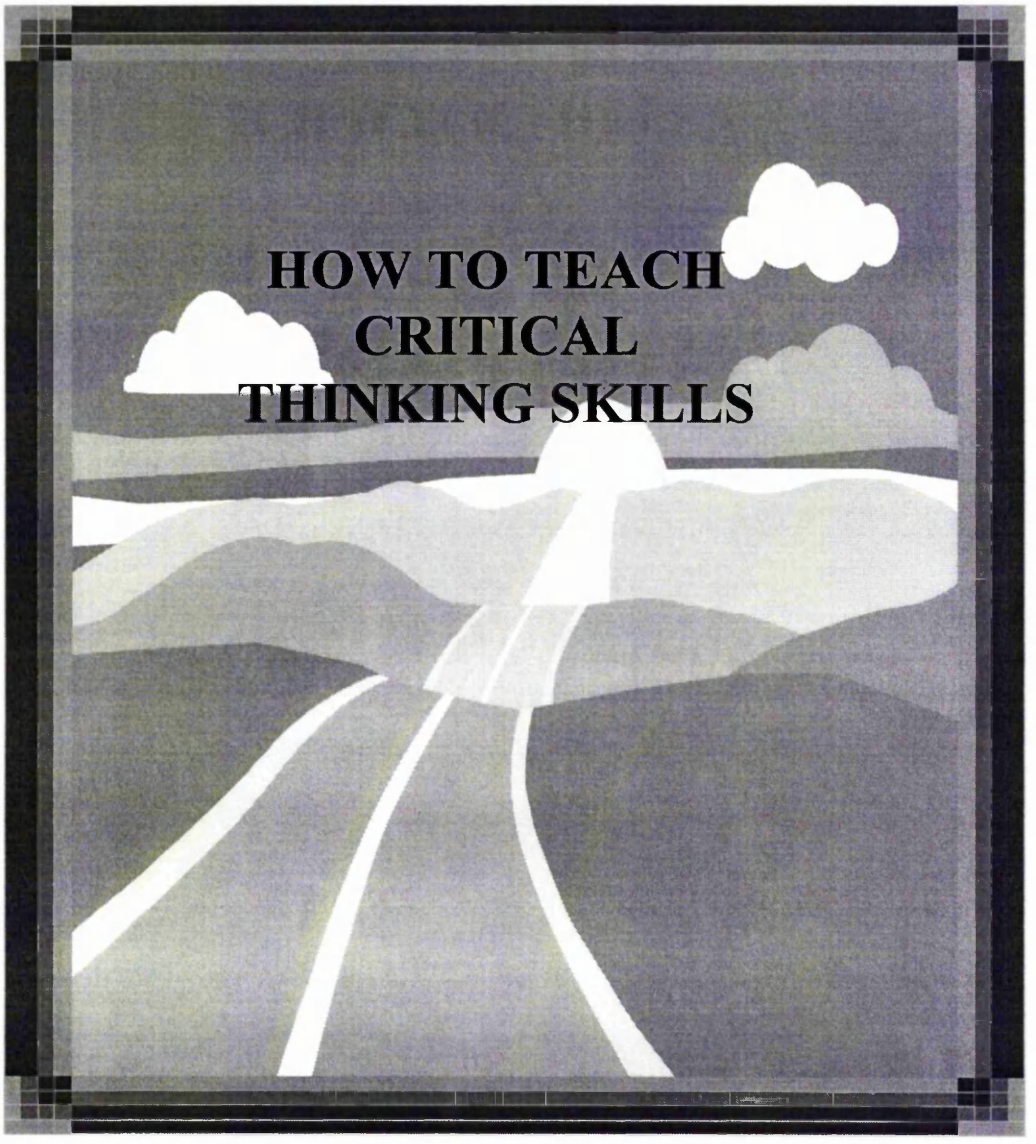




KEY POINTS

- The previous chapter focused on *what* critical thinking is and *why* it is important.
- This chapter highlights the importance of *knowledge*, *skills* and *dispositions* in instilling a critical thinking habit
- In order to be a critical thinker, a person needs to master three main types of knowledge; general heuristics, knowing the nature of knowledge and domain specific knowledge
- A critical thinker is someone who is adroit in cognitive skills as well as metacognitive skills; i.e. being aware of his/her thinking processes
- **T**ruth-seeking, **O**pen-mindedness, **A**nalyticity, **S**ystematicity, **I**nquisitiveness and **M**aturity are seven motivational factors that dispose someone to be a critical thinker

CHAPTER THREE



Objectives By the end of this chapter you will be able to:

- Apply Ennis's model of critical thinking in the real classroom situation
- Underline the main stages involved in teaching critical thinking in your science classroom
- Address the characteristic behaviours of the thoughtful classroom
- Identify the role of teachers in creating a thoughtful classroom

Contents

3.1 How to Teach Critical Thinking Skills

3.2 The Preferred Model - The Content Oriented View of Thinking and Its Implication for Science Education

3.3 "Interactive" or "Thoughtful" Classrooms

3.3.1 Physical Setting

3.3.2 Questioning Strategy

3.3.3 The Provision of Wait Time

3.3.4 Assessment Procedure

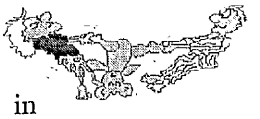
3.4 Summary

Assignment

Teaching of critical thinking in science instruction; the characteristics of a thoughtful classroom

3.1 HOW TO TEACH CRITICAL THINKING SKILLS

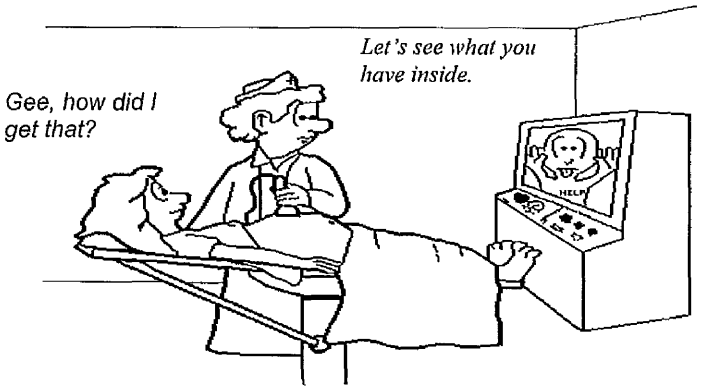
The literature on teaching thinking reflects two distinctive theoretical views. One view emphasises the *skills* and *strategies* involved in thinking and is based on thinking processes and the organisation of these processes in the human mind (e.g. Beyer 1978; De Bono 1978; 1985; Feuerstein *et. al.* 1980; Sternberg 1985). The other view focuses on the *content* of thinking and is based on research on expert-novice studies and on problem solving and reasoning in specific knowledge domains (e.g. Chi 1978; Glaser 1984; McPeck 1992; Prawat 1991; Swartz 1987). Since our aim is to infuse critical thinking in ordinary science classes, we shall concentrate on this latter approach.



3.2 THE PREFERRED MODEL - THE *CONTENT ORIENTED* VIEW OF THINKING AND ITS IMPLICATION FOR SCIENCE INSTRUCTION

The *content-oriented* view is about integrating thinking skills into conventional subject matter which in turn is used as a vehicle for thinking. It assumes that content and intellectual processes are mutually reinforcing and the interrelationship between knowledge structure and cognitive processes determines the kind of thinking skills to be exercised in the science classroom. Advocates of the *content-oriented* view claim that by understanding a particular discipline in depth, children come to comprehend the cognitive processes that they use during learning. Thus, by focusing primarily on a particular content, a teacher will help children gradually acquire the thinking skills as the issues and problems of the content become clear.

The content-oriented approach contains a composite of pedagogical techniques. One technique may be more appropriate for a particular learning situation than another technique. However, all the techniques have one common feature: they strive for child interaction in the learning process, which elsewhere is called "active learning". Here we shall see how this kind of approach can be applied in science classroom using Ennis's model of critical thinking as illustrated in **FIGURE 1.3 (please refer to Chapter One)**



Exercise

Refer back to FIGURE 1.3 (Chapter One):

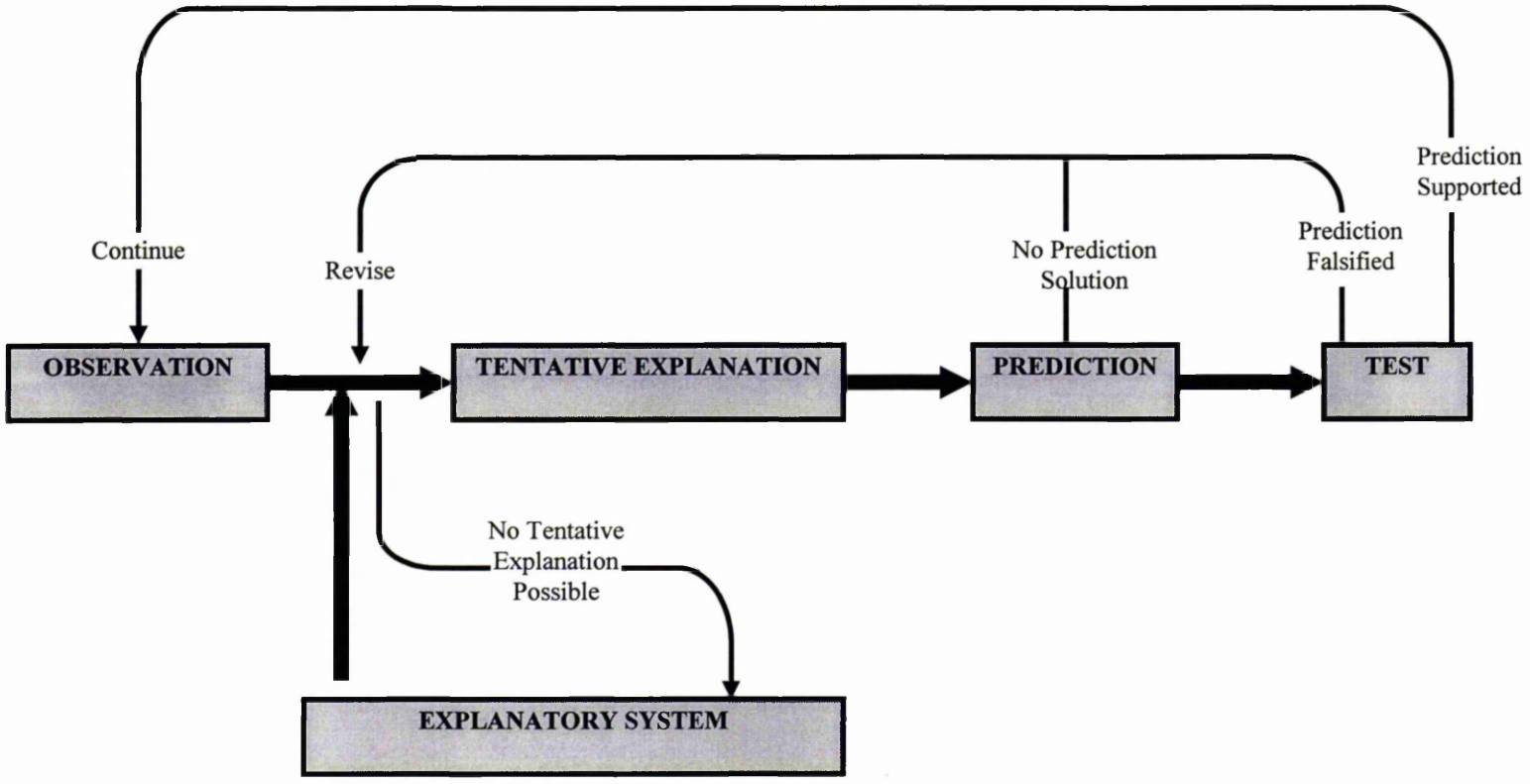
Do you think that Ennis's model of critical thinking can directly be applied in your science classroom? If your answer is "yes", suggest the main stages of teaching critical thinking by using this model. However, if your answer is "no", could you suggest at which point of the model several modifications might be needed and explain why?

Ennis's conception of critical thinking is subject specific, therefore the application of this concept will depend most importantly on the nature of a particular subject knowledge. In science, Ennis's concept of critical thinking can be applied as follows: Let say we want to teach the children about factors that are necessary for *photosynthesis*. The aim is to investigate whether light is needed for photosynthesis. Clearly the aim is to solve a problem; i.e. to determine whether plants need light for *photosynthesis*. In order to solve the problem, children need a disposition which motivates them to interact with the world. In the context of this example, it helps if children are able to discuss with others the nature of the problem and hence work towards the solution of the problem. At this point, their background knowledge in terms of problem solving skills and communication skills in science are vital for manoeuvring them towards the desired solution. In this way, not only are their problem solving and communication skills challenged, but this is done by co-operation with and tolerance to others. At this point (Basic Support), adroitness in scientific reasoning skills is vital for sketching an effective solution plan. Von Blum (1979)[1] provides a frame of reference for instilling such scientific habit of thought. (See **FIGURE 3.1**).

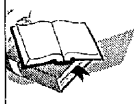
[1] Von Blum, R. (1979). Tribbles, Truth and Teaching: An Approach to Instruction in the Scientific Method. In J. Lochhead and J. Clemens (eds). *Cognitive Process Instruction: Research on Teaching Thinking Skills*. Pennsylvania: The Franklin Institute Press.

FIGURE 3.1

MODEL FOR AN ALTERNATIVE APPROACH TO TEACHING SCIENTIFIC REASONING



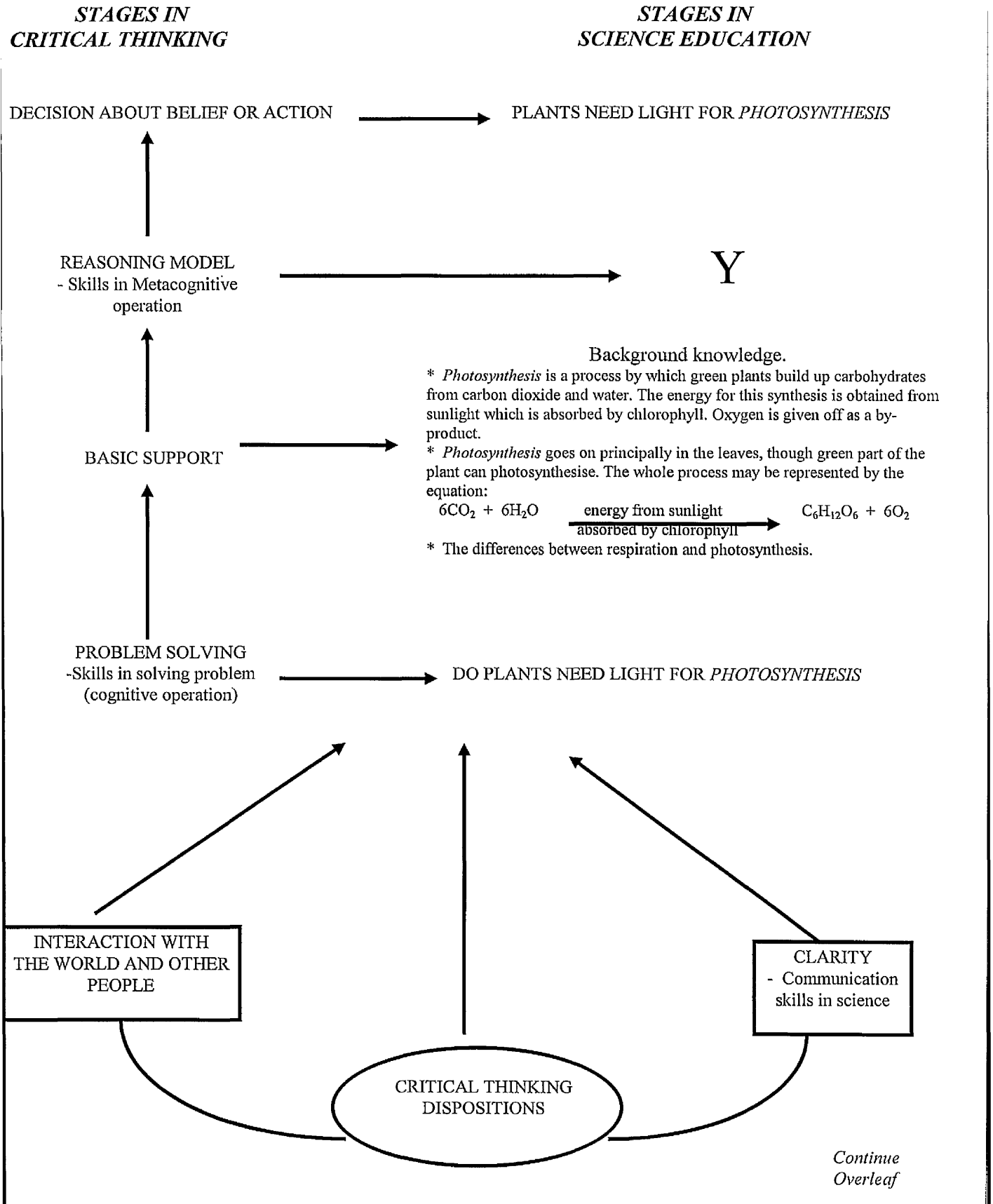
After first observing natural phenomena, the facts need to be obtained in order to provide a tentative solution to the problem (i.e. whether light is a necessary condition for *photosynthesis*). During this process, children recall their prior knowledge (about photosynthesis and green plants). The "explanatory system" in **FIGURE 3.1** claims Von Blum, is a formalisation of pertinent, tested principles that have been in the past useful in explaining aspects of the phenomena under consideration. By using the principles and concepts in the current explanatory system, children then form a tentative explanation of the observations. This tentative explanation (hypothesis) is then said to form a specific prediction (or set of predictions) that can, in turn, be tested and evaluated against the initial observations. An example of how Ennis's concept of critical thinking as depicted in **FIGURE 1.3** and Von Blum's model of scientific reasoning (see **FIGURE 3.1**) can be applied in Science Education is summarised in **FIGURE 3.2.**



Exercise

Quickly skim through the Syllabus Specification of the Integrated Secondary school Science Curriculum (Form One). Choose one topic and describe how you could teach that topic using the approach discussed in the preceding section. In your answer, discuss whether the three thinking components are being emphasised.

FIGURE 3.2



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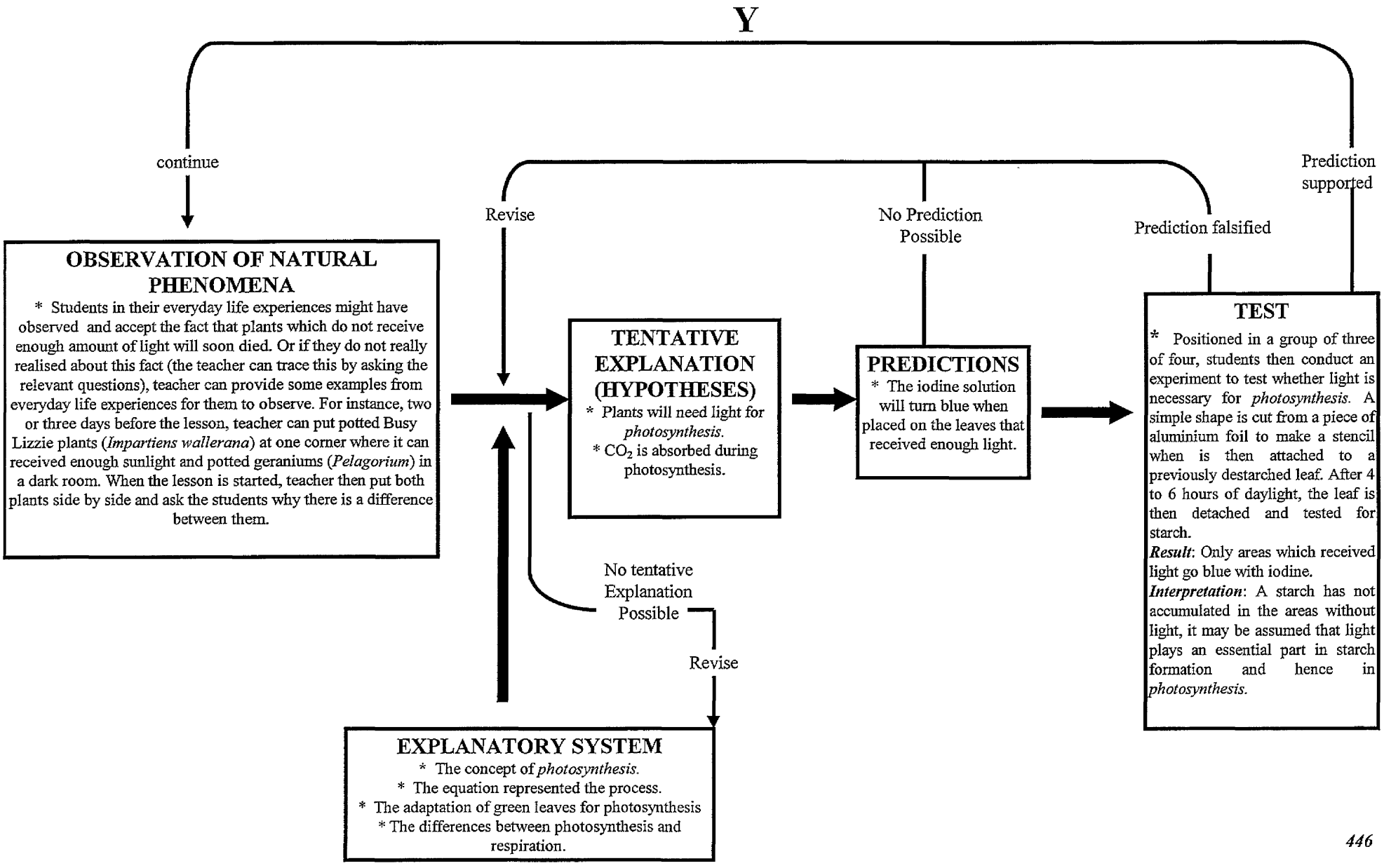

Y
continue
OBSERVATION OF NATURAL PHENOMENA
* Students in their everyday life experiences might have observed and accept the fact that plants which do not receive enough amount of light will soon died. Or if they do not really realised about this fact (the teacher can trace this by asking the relevant questions), teacher can provide some examples from everyday life experiences for them to observe. For instance, two or three days before the lesson, teacher can put potted Busy Lizzie plants (*Impartiens wallerana*) at one corner where it can received enough sunlight and potted geraniums (*Pelagorium*) in a dark room. When the lesson is started, teacher then put both plants side by side and ask the students why there is a difference between them.
Revise
TENTATIVE EXPLANATION (HYPOTHESES)
* Plants will need light for *photosynthesis.*
* CO_2 is absorbed during photosynthesis.
No Prediction Possible
PREDICTIONS
* The iodine solution will turn blue when placed on the leaves that received enough light.
Prediction falsified
TEST
* Positioned in a group of three of four, students then conduct an experiment to test whether light is necessary for *photosynthesis.* A simple shape is cut from a piece of aluminium foil to make a stencil when is then attached to a previously destarched leaf. After 4 to 6 hours of daylight, the leaf is then detached and tested for starch.
Result: Only areas which received light go blue with iodine.
Interpretation: A starch has not accumulated in the areas without light, it may be assumed that light plays an essential part in starch formation and hence in *photosynthesis.*
Prediction supported
No tentative Explanation Possible
Revise
EXPLANATORY SYSTEM
* The concept of *photosynthesis.*
* The equation represented the process.
* The adaptation of green leaves for photosynthesis
* The differences between photosynthesis and respiration.

3.3 THE "INTERACTIVE" OR "THOUGHTFUL" CLASSROOM

So far we have learnt how to teach critical thinking skills in our science classroom. However, in order to bring about effective teaching outcomes, successful teaching of critical thinking using this kind of approach requires a *"thoughtful"*[2] or *"interactive"*[3] classroom.

What is an *interactive* or *thoughtful* classroom?

Such a classroom is conceptualised as one where the goal is to engage children in what we predict will be challenging problems, guide their manipulation of information to solve them, and support their effort[4]. **TABLE 3.1** summarises the six "minimal criteria" for "classroom thoughtfulness". The teacher has a responsibility for developing a hospitable environment in which the teaching will take place.

TABLE 3.1

THE "MINIMAL CRITERIA" FOR "CLASSROOM THOUGHTFULNESS"[5]

SOURCE	CHARACTERISTICS OF BEHAVIOUR
GENERAL	1. There is general sustained examination of a few topics rather than superficial coverage of many 2. The lesson displays substantive coherence and continuity 3. Children are given time to think, to prepare responses to questions
TEACHER	4. The teacher asked challenging questions and/or structured challenging tasks 5. The teacher was a model of thoughtfulness (e.g. showing interest in children' ideas, and in alternate approaches to problems, showing how she/he thought through a problem, and acknowledging the difficulty of gaining a definitive understanding of problematic topics)
CHILDREN	6. Children offered explanations and reason for their conclusion

[2] Newmann, F.M. (1990). Higher Order Thinking in Teaching Social Studies: A Rational for The Assessment of Classroom Thoughtfulness. *Journal of Curriculum Studies, 22*(1), 41 - 56.
[3] Meyers, C. (1987). *Teaching Children to Think Critically.* London: Jossey-Bass Publisher.
[4] Newmann, F.M. (1990). *Ibid.*, p.45
[5] Newmann, F.M. (1990. *Ibid*,.p.50 - 53

Exercise

Information in TABLE 3.1 indicates that teacher has a responsibility for developing a hospitable environment in which the teaching will take place. Could you please suggest ways of how teacher could accomplish this?

A teacher can begin to accomplish this, for example, by rearranging classroom space to encourage reflection, using appropriate questioning strategies and providing children with enough "wait time". Additionally an appropriate method of child assessment must be provided.

3.3.1 Physical Setting

The physical setting of the classroom is very important for the development of critical thinking. With a little imagination, teachers can change the physical setting of the classroom by arranging chairs and desks in a variety of configurations: circles, rectangles, U-shapes or semicircles. Whatever the configuration the teacher chooses, the primary goal should be for everyone to able to see anyone else and communicate effectively. Obviously, this will lead to the division of children into small groups where they will communicate face to face for discussion or problem solving exercises. **FIGURE 3.3** gives suggestions of seating arrangements in the classroom.

3.3.2 Questioning Strategies

Questioning strategies are very important in implementing the content-oriented approach. Challenging children with higher cognitive level questions provokes thought rather than asking for simple recall[6&7]. Costa and Lowery (1989)[8] suggest the use of words like "compare", "hypothesise" and "conclude" as opposed to "what"and "list" which only lead to lower level cognitive operations.

---

[6] Swartz, R.J. and Perkins, D.N. (1989). *Teaching Thinking: Issues and Approaches*. California: Critical Thinking Press and Software

[7] Micheal, M.M. (1991). *Level of Classroom Thoughtfulness in Fifth Grade Social Studies Lesson: An Examination of Teacher Practice*. Unpublished Doctoral Dissertation, University of San Francisco, California

[8] Costa, A.L. and Lowery, L.F. (1989). *Techniques for Teaching Thinking*. California: Howest Publication

Additionally the questions asked must arouse children' interest so that they become actively engaged in the learning process. Meyers (1987)[9] suggests teachers begin their lesson with problem solving exercises or using short articles that relate to the concept that they are going to teach. Another way to encourage children to raise questions is to open the class by commenting on something happening in the school community that relates to the topic at hand. Whatever the technique used, the first five minutes of class time are vital in setting tone and focusing attention on the topic for the day.

Exercise

Whenever you ask questions, do you provide children with sufficient amount of time for them to think about the answer? If so, how long do you think is enough for children to think?

3.3.3 The provision of "Wait Time"

The provision of "wait time", sometimes called "think time", following the presentation of questions and ideas to children has been perceived as an important teacher behaviour in implanting the desired thinking habit in the "thoughtful classroom"[10&11]. This is because critical thinking demands a period of silence, reflection and incubation that are interrupted by words. Children need time to consider the new information, concepts and methodologies being presented to them. Research has shown that, with the provision of wait time averaging three to five seconds, not only are children' higher level cognitive operations increased, but the children-to-children interaction is greater and the number of questions children ask increases. Additionally, previously introvert children begin to contribute. In order to ensure that adequate time is provided, teachers should consciously manage the duration of pauses after solicitation and provide regular intervals of silence during instruction.

---

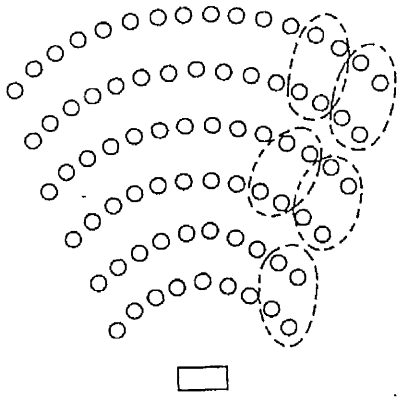
[9] Meyer, C. (1987). *Ibid,*

[10] Rowe, M.B. (1974). Wait Time as Instructional Variables: Their Influence on Language, Logic and Fate Control. *Journal of Research in Science Teaching, 11*(2), 81-94.

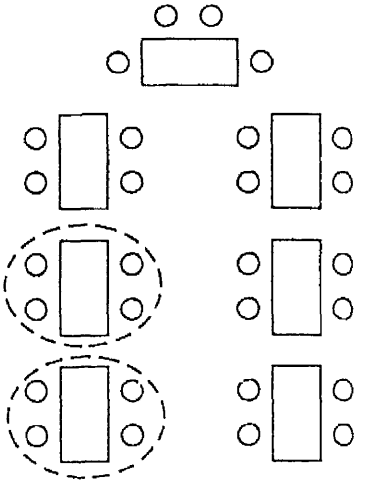
[11] Tobin, K.G. (1987). Using Wait Time to Improve the Quality of Classroom Discourse. *Review of Educational Research*, 57, 61-72.

FIGURE 3.3

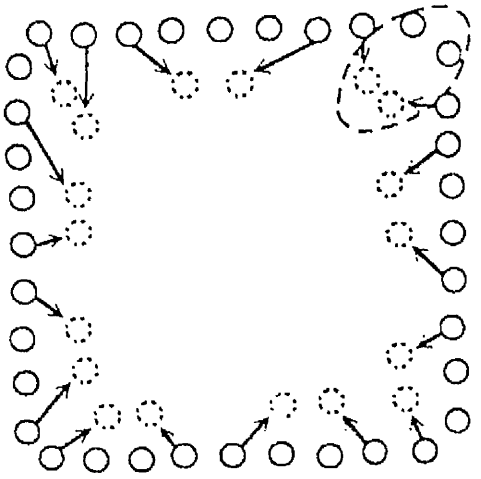
SEATING ARRANGEMENT FOR SMALL GROUP DISCUSSION AND FACE TO FACE COMMUNICATION



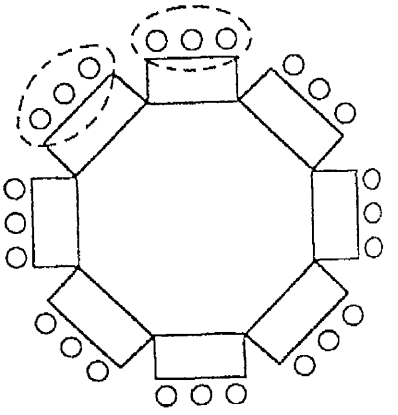
Lecture Hall



Tables in Horseshoe Arrangement



Movable Desks in Classroom



Tables in Circles

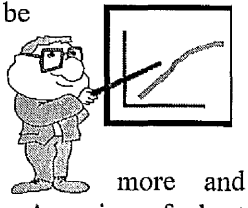
3.3.4 Assessment Procedure

As Sizer (1983) and others have argued, to improve children's critical thinking skills, we must make significant changes not only in our teaching, but also the testing of those skills[12]. In assessing critical thinking abilities, it is as important to know *how* children arrived at a conclusion, as it is to know the conclusion itself. Therefore it is suggested that written assignments or essay type tests would be more suitable than multiple choice tests because they provide opportunities for the children to puzzle over issues, to set things out and to formulate their own independent judgement. Though it is a very time-consuming process, it does allow the teachers to see more explicitly the children's thought processes and thus become more aware of their progress in developing new modes of critical thinking. Below are three characteristics of effective written assignments.

Stepwise Development of Skills

Children do not learn to think critically merely by acquiring increasingly complex layers of discipline content. Rather they need to practise actively the component skills of critical thinking. Depending upon the structure of scientific knowledge presented to the children, teachers should begin with simple operations, such as comparing, recognising basic issues, identifying key concepts and learning to ask appropriate questions. They can then build towards more complex and sophisticated skills such as recognising assumptions, hypothesising and creating critical arguments, which is a form of evaluation.

In assessing the children, teachers should bear in mind that critical thinking skills require continuous attention and monitoring[13]. Like motor skills, critical thinking skills must be practised over and over again at increasingly complex levels before it can be mastered. Assignments should be developed in a sequential manner so that children not only master the conceptual knowledge, but also critical thinking skills and dispositions that can serve as a foundation for future critical thinking endeavours. In designing these assessments, it is advisable to consider more and shorter assignments rather than fewer and longer ones. A series of short analytical assignments is more likely to produce desirable results than one major terms paper. Constructing, correcting and commenting on processes will also become easier. Additionally it gives immediate feedback to the children. Quiz, problem solving exercises, and brief simulations that can be discussed in class provide more powerful learning tools than papers and exams that are returned to children weeks or months after the test. By making children immediately aware of the strengths and weaknesses of their responses, prompt feedback plays an essential role in the trial-and-error efforts so necessary to the development of critical thinking.



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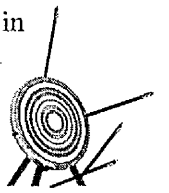
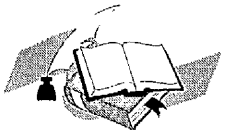
[12] Sizer, T.R. (1983). High School Reform: The Need for Engineering. *Phi Delta Kappan*, June 1983

[13] Baron, J.B. (1986). Evaluating Thinking Skills in the Classroom. In J.B. Baron, and R.J. Sternberg, (eds). *Teaching Thinking Skills: Theory and Practice.* New York: W.H. Freemann and CO.



Focus More on Real Problems and Issues

A second important characteristic of effective written assignments in critical thinking is that they relate to "real" problems and issues and draw upon children' own experiences. For example instead of asking the child "what are the factors that affect the strength of wood?", teachers can give children *a "decorating problem"* as follows: Sally and Sam watched their Mum and Dad decorating. To reach a high place, their Dad puts a plank of wood between two chairs. Then their Mum said, " the plank will bend too much. You are too heavy". Sally said, "if you use a different plank, it won't bend as much". Sam then added, " if you use a wider plank, it won't bend as much". Then teacher might ask the children who was right and ask them to find out the factors that affect the strength of wood. It is important to make the children feel that they are struggling with real problems and issues.



Exercise

The Characteristics of Behaviour in Thoughtful Classroom

GENERAL: i) _____

ii) _____

iii) Provision of enough wait time

TEACHER: i) Teacher ask challenging questions and/or structured challenging task

ii)

_____

CHILDREN: i) _____

Additionally, successful creation of thoughtful classroom will also require teacher to _____ and _____. It is suggested that written assignments and essay type tests would be more suitable than _____. In designing an effective written assignments, teacher must _____and _____.

You could find the answers of these questions by referring back to section §3.3 - 3.3.4.

ASSIGNMENT

During your teaching practise, ask a colleague if you can sit on a lesson for 30 minutes. Record on a piece of paper whether he/she is implementing the key concepts of teaching critical thinking skills. You are also require to observe the structure and characteristics of behaviour of the classroom.

Write a couple of pages on your findings and conclusions.

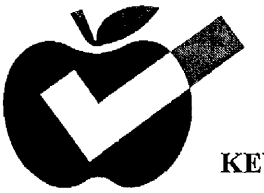
Feedback:

In order to determine whether the key concepts of teaching critical thinking skills is used in the science instruction, we have to consider all the elements that involved in our discussion. For example:

The physical setting of the classroom;
Teacher's questioning strategies;
The provision of wait time; and
Assessment procedure

3.4 SUMMARY

Infusing critical thinking skills in science classroom requires more than the application of one selected theoretical model of critical thinking. Considering the nature of science as a subject and the psychological environment of the classroom, several modifications are needed. Teachers must create a thoughtful classroom conducive for the development of critical thinking abilities. To solidify your understanding of the whole unit, read the following key points and assimilate all the theoretical ideas presented and implement them in your science instruction.



KEY POINTS

- This chapter provides an overview of how to teach critical thinking skills in science classroom.
- In order to teach critical thinking using Ennis's model of critical thinking, Von Blum's model of scientific reasoning need also to be applied.
- Successful teaching of critical thinking requires a *"thoughtful"* or *"interactive"* classroom. **TABLE 3.1** summarises six minimal criteria of classroom thoughtfulness.
- Teachers are responsible for developing a *thoughtful* or *interactive* environment. They can accomplish this, for example, by setting a suitable seating arrangement, changing their questioning strategies, providing enough wait time and changing the methods of assessment.

SUMMARY OF THE UNIT

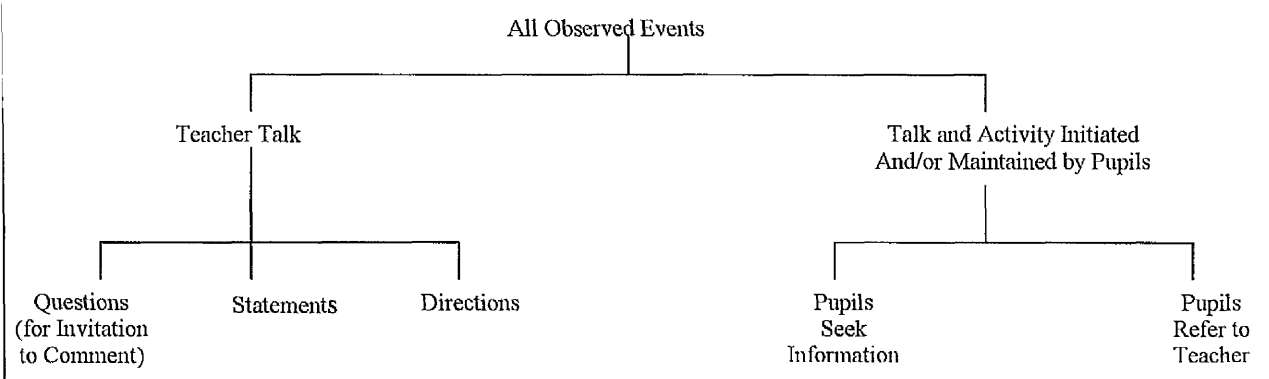
The nature of science as a subject and the aim of the Integrated Secondary School Science Curriculum that underpin the teaching and learning processes make the science classroom a fertile ground for nurturing and developing critical thinking skills. In order to inculcate critical thinking abilities in our children, effort and initiative on part of the teachers seems crucial. Besides possessing an adequate theoretical knowledge about science *per se*, teachers must also be equipped with the theoretical foundations of how to infuse critical thinking skills in their science instruction. In doing so, teachers must emphasise the importance of the affective domain since critical thinking encompasses skills in cognitive and metacognitive skills, knowledge about science and also dispositions that intrinsically motivate them to think critically.

Critical thinking is conceptualised by Ennis as *"reasonable and reflective thinking that is focused upon deciding what to believe or do"*. Such conceptualisation is chosen because it fits the science subject and its implementation can be realised by following the Islamic Working Paradigm that directs the orientation of curriculum implementation in Malaysia. Thus the application of Ennis's model in delivering scientific knowledge will mould our children to self-acquire knowledge, perform activities of science either theoretically or experimentally, administer, manage and make decision about scientific activities while at the same time help them to grow and develop at the spiritual and effective levels.

APPENDIX H

THE SCEINCE TEACHING OBSERVATION SCHEDULE (STOS)

THE SCIENCE TEACHING OBSERVATION SCHEDULE (STOS)



1 TEACHER TALK

1a Teacher asks questions (or invites comments) which are answered by:

a_1	recalling facts and principles	a_1
a_2	applying facts and principles to problem solving	a_2
a_3	making hypothesis or speculation	a_3
a_4	designing of experimental procedure	a_4
a_5	direct observation	a_5
a_6	interpretation of observed or recorded data	a_6
a_7	making inferences from observations or data	a_7

1b Teacher makes statements:

b_1	of fact and principles	b_1
b_2	of problems	b_2
b_3	of hypothesis or speculation	b_3
b_4	of experimental procedure	b_4

1c Teacher directs pupils to sources of information for the purpose of:

c_1	acquiring or confirming facts or principles	c_1
c_2	identifying or solving problems	c_2
c_3	making inferences, formulating or testing hypotheses	c_3
c_4	seeking guidance on experimental procedure	c_4

2 TALK AND ACTIVITY INITIATED AND/OR MAINTAINED BY PUPILS

2d Pupils seek information or consult for the purpose of:

d_1	acquiring or confirming facts or principles	d_1
d_2	identifying or solving problems	d_2
d_3	making inferences, formulating or testing hypotheses	d_3
d_4	seeking guidance on experimental procedure	d_4

2e Pupils refer to teacher for the purpose of:

e_1	acquiring or confirming facts or principles	e_1
e_2	identifying or solving problems	e_2
e_3	seeking guidance when making inferences, formulating or testing hypotheses	e_3
e_4	seeking guidance on experimental procedure	e_4

0 3 6 9 12 15 18 21 24 27 30

APPENDIX I

PERMISSION LETTER FROM THE EDUCATIONAL PLANNING AND RESEARCH DIVISION, MINISTRY OF EDUCATION

BAHAGIAN PERANCANGAN DAN
PENYELIDIKAN PENDIDIKAN,
KEMENTERIAN PENDIDIKAN,
PARAS 2, 3 DAN 5, BLOK J,
PUSAT BANDAR DAMANSARA,
50604 KUALA LUMPUR

Telefon: 2556900
Kawat: "PENDIDIKAN"
Faks: 03-2554960

Ruj. Tuan:

Ruj. Kami: KP(BPPP) 13/15

Tarikh: 10 Mac 1997

Cik Kamisah bt Osman,
No. 22, Batu 11,
Jalan Beman,
45500 Tg.Karang, Selangor.

Puan,

Kebenaran Bagi Menjalankan Kajian Ke Sekolah-Sekolah, Jabatan-Jabatan Dan Institusi-Institusi Di Bawah Kementerian Pendidikan Malaysia

Adalah saya dimaklumkan bahawa permohonan puan untuk menjalankan kajian mengenai

"Inculcating And Encouraging The Use Of Critical Thinking Skills In Science Student Teachers In Malaysia".

dilulus/tidak.

2. Kelulusan ini adalah berdasarkan kepada tajuk apa yang terkandung di dalam cadangan penyelidikan yang puan kemukakan ke Bahagian ini. Kebenaran bagi menggunakan sampel kajian perlu diperolehi daripada Ketua Bahagian/Pengarah Pendidikan Negeri yang berkenaan.

3. Puan juga dikehendaki menghantar senaskhah hasil kajian puan ke Bahagian ini sebaik sahaja selesai kelak.

Sekian.

"BERKHIDMAT UNTUK NEGARA"

"CINTAILAH BAHASA KITA"

Saya yang menurut perintah,

(DR. HJ. KARIM B. MD. NOR)
b.p. Pengarah Perancangan dan Penyelidikan Pendidikan,
b.p. Pendaftar Besar Sekolah-Sekolah dan Guru-Guru,
Kementerian Pendidikan.

APPENDIX J

PERMISSION LETTER FROM THE STATE OF SELANGOR, DEPARTMENT OF EDUCATION

جابتن ڤندیديقن سلاڠور
JABATAN PENDIDIKAN SELANGOR
TINGKAT BAWAH, 8 - 11,
WISMA MPSA,
40604 SHAH ALAM,
SELANGOR.

Telefon : 03 559 8843
Fax : 03 550 2133

Ruj. Tuan:

Ruj. Kami: Bil.(98)dlm.JPS.41989/
Jld.30
Tarikh: 19 Jun 1997

Kamisah Osman
Jabatan Perkaedahan dan
Amalan Pendidikan
Fakulti Pendidikan
Universiti Kebangsaan Malaysia
43600 Bangi
Selangor Darul Ehsan

Tuan,

KEBENARAN MENJALANKAN KAJIAN KE SEKOLAH-SEKOLAH

Tajuk : " **Inculcating And Encouraging The Use Of Critical Thinking Skills In Science Student Teachers In Malaysia.** "

Berdasarkan kepada surat : KP(BPPP)13/15Jld.48(62).
Bertarikh : **10 Mac 1997.**

Surat tuan bertarikh 17 Jun 1997 berhubung perkara di atas adalah dirujuk dan sukacita dimaklumkan bahawa Jabatan ini tiada halangan pihak tuan hendak menjalankan kajian tersebut di **sekolah-sekolah yang disenaraikan pada Jun 1997.**

2. Walau bagaimanapun persetujuan daripada pihak Pengetua sekolah-sekolah yang terlibat hendaklah diperolehi terlebih dahulu supaya beliau dapat bekerjasama dan seterusnya memastikan bahawa kajian yang dijalankan hanya bertujuan sebagaimana yang tuan nyatakan itu sahaja tanpa melibatkan gangguan terhadap perjalanan sekolah serta tiada unsur-unsur paksaan semasa kajian berkenaan dijalankan. Adalah diingatkan Pengetua berhak menerima/menolak program tuan.

3. Tuan juga dikehendaki menghantar senaskah hasil kajian tuan ke Bahagian ini (Unit Perhubungan Dan Pendaftaran) sebaik sahaja selesai kelak.

Sekian, terima kasih.

(Sila catatkan rujukan Jabatan ini apabila berhubung)

"BERKHIDMAT UNTUK NEGARA"

(HAJI NORDIN BIN HAJI DAHLAN)

(HAJI NORDIN BIN HAJI DAHLAN)
b.p. Pendaftar Sekolah-Sekolah
Negeri Selangor Darul Ehsan.

s.k 1. Ketua Sektor Pengurusan Sekolah,
Jabatan Pendidikan Selangor.

2. Ketua Sektor Pembangunan Manusia,
Jabatan Pendidikan Selangor.

3. Dekan,
Jabatan Perkaedahan Dan Amalan Pendidikan,
Fakulti Pendidikan, UKM.

4. Pegawai Pendidikan Daerah Hulu Langat.

5. Pegawai Pendidikan Daerah Petaling.

6. Pegawai Pendidikan Daerah Klang.

7. Pegawai Pendidikan Daerah Kuala Langat.

MAY/ika/190697

APPENDIX K

ANALYSIS OF THE SIMPLE INTERACTION EFFECT ON THE ATTITUDE DATA

TABLE 1

MULTIVARIATE ANALYSIS OF VARIANCE (3 x 7)

(METHOD OF INTERVENTION STRATEGY BY SUB-SCALES AT PRE-TEST)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F
Between subjects					
Method	91.67	2	45.83	1.27	.283
Within + Residual	4604.56	128	35.83		
Within subjects					
Subscales	7446.80	6	1241.13	82.57	.000*
Method by Sub-scales	115.05	12	9.59	.64	.811
Within + Residual	11543.79	768	15.03		

* p <.05

TABLE 2

MULTIVARIATE ANALYSIS OF VARIANCE (3 x 7)

(METHOD OF INTERVENTION STRATEGY BY SUB-SCALES AT POST-TEST)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F
Between subjects					
Method	1302.95	2	651.48	12.00	.000*
Within + Residual	6947.00	128	54.27		
Within subjects					
Subscales	8201.35	6	1366.89	81.79	.000*
Method by Sub-scales	394.90	12	32.91	1.97	.024*
Within + Residual	12835.03	768	16.71		

* p <.05

TABLE 3

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE POST-TEST SCORE BY METHOD OF INTERVENTION STRATEGY

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	2	9120.677	4560.339	12.004	.000*
Within Groups	128	48629.0	379.914		
Total	130	57749.6			

MULTIPLE COMPARISONS
(Summary of Bonferroni Tests)

Method of Instruction	Mean Difference	Std Error	Sig.
Critical Thinking Critical Thinking Self - Instructed by Lecture Instructed	17.37*	4.132	000
Critical Thinking Self - Instructed by Control Group	17.78*	4.182	. 000
Critical Thinking Lecture Instructed by Control Group	.41	4.205	1.000

* The mean difference is significant at the 0.05 level

TABLE 4

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE POST-TEST SCORE BY METHOD OF INTERVENTION STRATEGY (TRUTH SEEKING SCALE)

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	2	453.654	226.827	9.109	.000*
Within Groups	128	3187.246	24.900		
Total	130	3640.901			

*The mean difference is significant at the 0.05 level

TABLE 5

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE POST-TEST SCORE BY METHOD OF INTERVENTION STRATEGY (OPEN MINDEDNESS SCALE)

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	2	136.357	68.179	3.900	.000*
Within Groups	128	2237.719	17.482		
Total	130	2374.076			

*The mean difference is significant at the 0.05 level

TABLE 6

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE POST-TEST SCORE BY METHOD OF INTERVENTION STRATEGY (ANALYTICITY SCALE)

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	2	41.030	20.515	1.374	.257
Within Groups	128	1910.940	14.929		
Total	130	1951.969			

TABLE 7

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE POST-TEST SCORE BY METHOD OF INTERVENTION STRATEGY (SYSTEMATICITY SCALE)

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	2	269.751	134.876	8.394	.000*
Within Groups	128	2056.676	16.068		
Total	130	2326.427			

*The mean difference is significant at the 0.05 level

TABLE 8

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE POST-TEST SCORE BY METHOD OF INTERVENTION STRATEGY (SELF CONFIDENCE SCALE)

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	2	57.811	28.906	.893	.412
Within Groups	128	4142.067	32.360		
Total	130	4199.878			

TABLE 9

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE POST-TEST SCORE BY METHOD OF INTERVENTION STRATEGY (INQUISITIVENESS SCALE)

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	2	139.433	69.717	4.035	.000*
Within Groups	128	2211.452	17.277		
Total	130	2350.885			

*The mean difference is significant at the 0.05 level

TABLE 10

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE POST-TEST SCORE BY METHOD OF INTERVENTION STRATEGY (MATURITY SCALE)

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	2	599.817	299.908	9.512	.000*
Within Groups	128	4035.924	31.531		
Total	130	4635.740			

*The mean difference is significant at the 0.05 level

APPENDIX L

THE SCHEFFE *POST HOC* ANALYSIS

TABLE 1

MULTIPLE COMPARISONS
(Summary of ScheffeTests)

Method of Instruction	Mean Difference	Std Error	Sig.
Critical Thinking Critical Thinking Self - Instructed by Lecture Instructed	.89*	.216	.000
Critical Thinking Self - Instructed by Control Group	2.79*	.219	.000
Critical Thinking Lecture Instructed by Control Group	1.90*	.220	.000

*The mean difference is significant at the 0.05 level

APPENDIX M

ANALYSIS OF SIMPLE INTERACTION EFFECT ON THE EVALUATION DATA

TABLE 1

MULTIVARIATE ANALYSIS OF VARIANCE (3 x 4)

(METHOD OF INTERVENTION STRATEGY BY MAJOR OF SPECIALISATION AT KNOWLEDGE LEVEL)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F
Method	1.89	2	.95	4.98	.008*
Major	1.48	3	.49	2.60	.05
Method by Major	1.60	6	.27	1.40	.220
Within + Residual	22.63	119	.19		

* p <.05

TABLE 2

MULTIVARIATE ANALYSIS OF VARIANCE (3 x 4)

(METHOD OF INTERVENTION STRATEGY BY MAJOR OF SPECIALISATION AT COMPREHENSION LEVEL)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F
Method	12.65	2	6.32	18.54	.000*
Major	2.23	3	.74	2.18	.094
Method by Major	2.48	6	.41	1.21	.304
Within + Residual	40.59	119	.34		

* p <.05

TABLE 3

MULTIVARIATE ANALYSIS OF VARIANCE (3 x 4)

(METHOD OF INTERVENTION STRATEGY BY MAJOR OF SPECIALISATION AT APPLICATION LEVEL)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F
Method	14.01	2	7.01	15.26	.000*
Major	2.68	3	.89	1.94	.126
Method by Major	2.45	6	.41	.89	.505
Within + Residual	54.62	119	.46		

* p <.05

TABLE 4

MULTIVARIATE ANALYSIS OF VARIANCE (4x 3)

(MAJOR OF SPECIALISATION BY EVALUATION SCORE AT SELF-INSTRUCTED METHOD OF INTERVENTION STRATEGY)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F
Between subjects					
Major	2.07	3	.69	3.10	.037*
Within + Residual	9.14	41	.22		
Within subjects					
Evaluation score	9.89	2	4.94	25.41	.000*
Major by Evaluation Score	2.30	6	.38	1.97	.080
Within + Residual	15.95	82	.19		

* p <.05

TABLE 5

MULTIVARIATE ANALYSIS OF VARIANCE (4x 3)

(MAJOR OF SPECIALISATION BY EVALUATION SCORE AT LECTURE INSTRUCTED METHOD OF INTERVENTION STRATEGY)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F
Between subjects					
Major	.26	3	.09	.18	.908
Within + Residual	18.74	40	.47		
Within subjects					
Evaluation score	23.58	2	11.76	39.19	.000*
Major by Evaluation Score	1.33	6	.22	.73	.623
Within + Residual	20.47	80	.30		

* p <.05

TABLE 6

MULTIVARIATE ANALYSIS OF VARIANCE (4x 3)

(MAJOR OF SPECIALISATION BY EVALUATION SCORE AT CONTROL GROUP)

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F
Between subjects					
Major	2.49	3	.83	2.71	.059
Within + Residual	11.65	38	.31		
Within subjects					
Evaluation score	21.53	2	10.77	21.36	.000*
Major by Evaluation Score	3.88	6	.65	1.28	.275
Within + Residual	38.30	76	.50		

* p <.05

TABLE 7

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE KNOWLEDGE SCORE BY MAJOR OF SPECIALISATION

(SELF-INSTRUCTED METHOD OF INTERVENTION STRATEGY)

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	3	7.1E-2	2.4E-02	.530	.664
Within Groups	41	1.840	4.5E-02		
Total	44	1.911			

TABLE 8

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE COMPREHENSION SCORE BY MAJOR OF SPECIALISATION

(SELF-INSTRUCTED METHOD OF INTERVENTION STRATEGY)

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	3	.576	.192	.908	.445
Within Groups	41	8.668	.211		
Total	44	9.244			

TABLE 9

ANALYSIS OF VARIANCE COMPARING THE MEANS OF THE APLICATION SCORE BY MAJOR OF SPECIALISATION

(SELF-INSTRUCTED METHOD OF INTERVENTION STRATEGY)

Source of Variation	DF	Sum of Squares	Means Squares	F Ratio	P Prob.
Between Groups	3	3.721	1.240	3.486	.024*
Within Groups	41	14.590	.356		
Total	44	18.311			

*The mean difference is significant at the 0.05 level

APPENDIX N

THE *KRUSKAL – WALLIS* TEST

TABLE 1

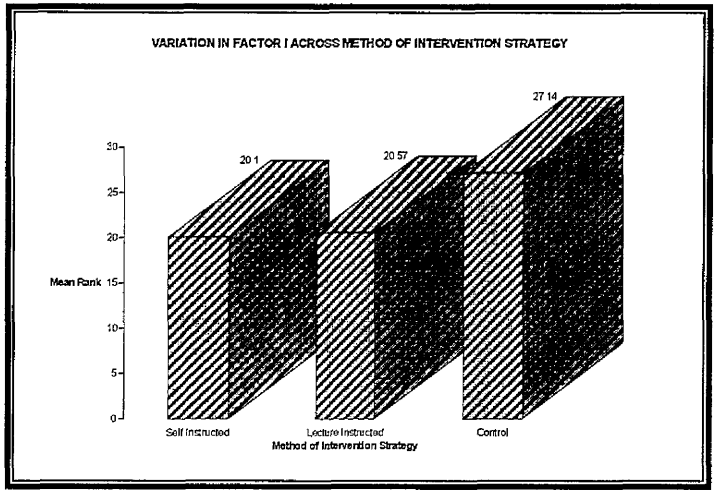
KRUSKAL-WALLIS TEST COMPARING MEDIANS OF FACTOR I ("ENQUIRER"), II ("PROBLEM SOLVER"), AND III ("INFORMER")

	Method of Intervention Strategy	N	Mean Rank
ENQUIRER	Self - Instructed	15	20.10
	Lecture Instructed	15	20.57
	Control	14	27.14
PROBLEM SOLVER	Self - Instructed	15	25.00
	Lecture Instructed	15	24.53
	Control	14	17.64
INFORMER	Self - Instructed	15	24.43
	Lecture Instructed	15	20.00
	Control	14	23.11

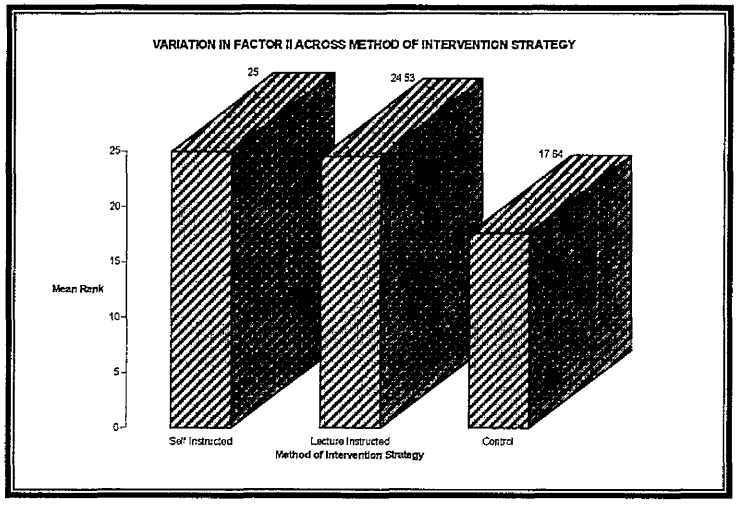
	ENQUIRER	PROBLEM SOLVER	INFORMER
CHI-SQUARE	**2.693**	**2.946**	**.939**
DF	**2**	**2**	**2**
ASYMP. SIG.	**.260**	**.229**	**.625**

FIGURE 1

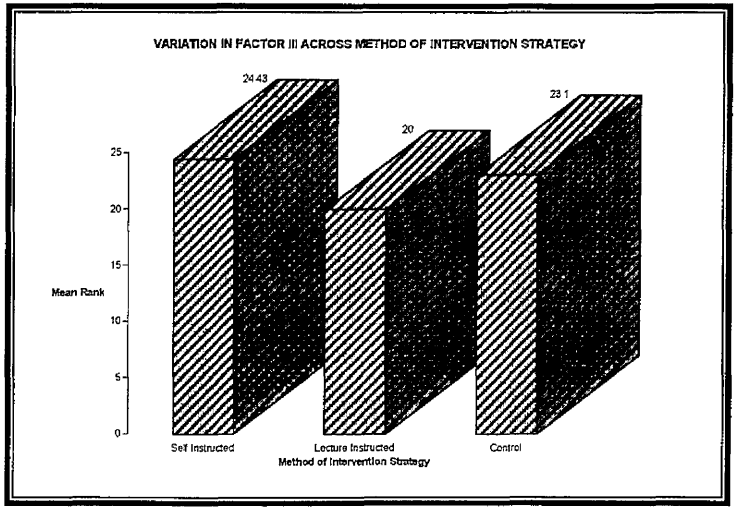
VARIATIONS IN THE FACTORS ACROSS METHOD OF INTERVENTION STRATEGY



ENQUIRER



PROBLEM SOLVER



INFORMER

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